

**EXPERIMENTAL INVESTIGATION ON CONCRETE BY PARTIALLY
REPLACING SAND WITH CRUSHED STONE DUST**

M.Sc. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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**EXPERIMENTAL INVESTIGATION ON CONCRETE BY PARTIALLY
REPLACING SAND WITH CRUSHED STONE DUST**

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**A THESIS SUBMITTED TO THE
DEPARTMENT OF CIVIL ENGINEERING,
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SEPTEMBER, 2021

HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY
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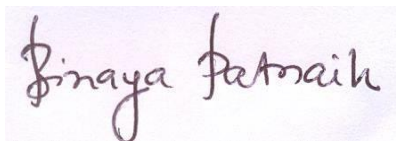
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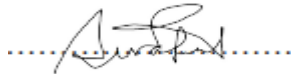
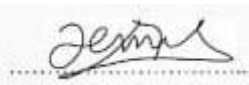
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DEDICATION

First and foremost, praises and thanks to God!

Secondly,

To

My Family

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LIST OF ABBREVIATIONS

ACI	America Concrete Institute
ASTM	America Society of Testing Material
CM	Cement Mortar
CGF	Crushed Granite Fine
CRP	Crushed Rock Powder
FA	Fine aggregate
FM	Fineness Modulus
Wt.	Weight
W/c	Water cement ratio

ABSTRACT

Concrete is the most widely used construction material in urban areas of Ethiopia. Out of different constituent materials of concrete, fine aggregate is one of the key materials and river sand is the most common form of fine aggregate used in Ethiopia. However, with increased dwelling demand and construction activities in Ethiopia, the demand for river sand has increased which is leading to large scale depletion of river bed and increasing cost of sand to be afforded by common man. This has compelled the researchers to find alternative sustainable materials in place of river sand which can be easily used as fine aggregate in concrete.

Various industrial wastes and agrowastes have been tried as an alternative to river sand and the results are promising. This research work aims at examining the viability of using crushed stone dust as a fine aggregate in concrete. So, in this research work an attempt has been made to experimentally investigate the mechanical and durability properties of concrete using crushed stone dust as fine aggregate. Different concrete mix samples were prepared by using quarry dusts as fine aggregate in different proportions from 30% to 70% by volume and the strength and durability properties were compared with that of controlled concrete at several curing period. The experimental result revealed that, adding crushed stone dust as a partial replacement of sand in concrete has positive influence on the strength and durability properties of concrete.

Keywords: Concrete, stone dust, river sand, workability, compressive strength, durability

CHAPTER ONE

1. INTRODUCTION

1.1 General

At present, construction industry is growing exponentially due to several other factor besides increasing developmental activities and this results in huge demand of construction materials.

Among these materials Concrete is most widely used construction material. Conventionally Concrete is a composite material made of cement, fine aggregate, coarse aggregate and water. Its Major components are aggregates which are usually available in natural form. Fine Aggregate used in concrete is usually river sand available locally or at nearby location.

The naturally available source of fine aggregate is limited as such conservation of the same is inevitable. Going for alternative and supplementary material which can be used as partial or full replacement of conventional material can play a vital role in conservation of natural resources. The demand for river sand in the construction industry has consequently increased due to the extensive use of concrete resulting in the reduction of sand sources and increase in price. In some areas the river sand is not easily available where the long-distance transportation might be a must which in turn results increase in its cost.

The large-scale depletion of natural sand sources creates also the environmental problem such as erosion and failure of river banks, lowering of river beds, saline water intrusion into the land. Thus, an investigation is needed to identify a suitable substitute that is eco-friendly, inexpensive and better for strength and durability performance. In this connection the use of stone dust as fine aggregate with partial or full replacement may be a promising alternative in concrete making.

According to Balamurgan et al., 2013 Quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand giving higher strength at 50% replacement. Nagpal et al., 2013 also investigated that using crushed stone dust as fine aggregate in concrete increase its compressive, flexural and tensile strength.

As it has been observed by Franklin et al., 2014 that 40% replacement of fine aggregate with stone dust is adaptable.

The study of Quadri et al., 2013 has revealed that the replacement of natural sand by crusher dust increased the compressive strength of concrete by 5-22% and it was also found that amongst all the mixes, the highest compressive strength was obtained for 40% replacement of sand by crusher dust.

According to M S Shetty, 2013 the required slump could not be achieved by natural sand with given parameter of mix design. But with the use of manufactured sand with proper shape, surface texture, desirable grading to minimize void content, a highly workable mix with the given parameter of mix design, was achieved.

In the investigation carried out by Mahzuz et al., 2011 the compressive strength of concrete from stone powder showed 14.76% higher value than that of the concrete made of normal sand. Suribabu et al., 2015 also found that the compressive and flexural strength of concrete made of Quarry Rock Dust are nearly 10% more than the conventional concrete.

In this study the comparative analysis was carried out on the concrete made with stone dust and conventional concrete to evaluate the suitability of the crushed stone dust to replace the river sand there by evaluating the properties of both conventional and stone dust concretes under different conditions.

To do this the concrete mixes produced by using different proportions of the stone dust to replace river sand and evaluation was carried out on both compressive strength and durability properties.

To ensure these different concrete mixes produced with different proportion of the stone dust to replace river sand and water curing before doing all the tests was carried out for 7 and 28 days of curing period except the test for workability of the fresh concrete in which the slump test was done before all the concrete mixes prepared.

On the ways of this research the optimum replacement proportion of stone dust was tried to estimated.

1.2 Objective of the Study

1.2.1 General objective of the study

The general objective of this study is to investigate the suitability of stone dust as a fine aggregate in concrete by conducting various strength and durability studies of concrete.

1.2.2 Specific objective of the study

- To investigate the strength properties of concrete such as compression, by partially replacing river sand with stone dust.
- To investigate the effect of elevated temperature on stone dust concrete
- To investigate the water absorption capacity of stone dust concrete.
- To investigate the influence of acid on stone dust concrete.
- To estimate the optimum percentage of stone dust as a fine aggregate in concrete.

1.3 Statement of the Problem

Now a day the construction industry expanding exponentially which in turn resulted in increased demand on the use of concrete material which leads to a high amount use of naturally existing river sand. But as it is a limited resource, the natural river sand is becoming depleted and this is a big challenge for coming generations to use this material to fulfill their demand in construction industry.

Therefore, it is a must to find out a new option to replace sand and save it for coming new generations.

In addition to this as mining for river sand is very high a landfills problems and river bed depletion becoming a big problem for our environment.

Also, in some areas there is no enough sand availability and due to this a long-distance transportation resulted increased cost incurring and delay for construction projects.

To solve these problems many researches were done and most of them have no doubt on suitability of stone dust in concrete production by replacing sand. But as the reports of their findings shows there are the variations of the results on the same researching issues. Therefore, further investigations and researching is important to validate the results and to insure the possibility of stone dust to replace river sand in concrete production.

Also, there is not that much enough researches that was done on the durability properties of the concrete that made by replacing sand with stone dust and it requires further researching as the durability properties of the concrete is very important in concrete production.

1.4 Research Significance

In some areas common river sand is expensive due to excessive cost of transportation from natural sources. Also, large-scale depletion of these sources creates environmental problems. As its limited source and environmental pollution constraints make the use of river sand less attractive, a substitute or replacement product for concrete Industry needs to be found. In such a situation the quarry rock dust can be an economic alternative to the river sand. Therefore, in this research the properties of the concrete and its resistance to different conditions studied and compared to that of naturally existing river sand to value the stone dust as a sand replacement to produce concrete mix.

1.5 Methodology

The research started off with problem identification which is done through a brief literature reading. Upon obtaining the identified problem a thorough literature review was conducted to provide an in depth understanding on Concrete with crushed stone dust, focusing on its Mechanical properties, fresh properties of Concrete with crushed stone dust, durability, mix design considerations, mixing, placing, finishing and an identification of economic value of using stone dust as a fine aggregate rather than using natural sand presented.

Since the research specifically emphasized on concrete mixed with stone dust, the literature review will provide further understanding on the use of crushed stone dust in the production of concrete and construction industry. Therefore, practical application of concrete mixed with crushed stone dust was also referred from existing literatures that was done by different authors.

Measurement of properties of concrete with crushed stone dust is very important for practice as well as for research efforts. Therefore, an overview of currently available and modified test methods used to evaluate the strength and durability of crushed stone dust mixed concrete will also be provided as a supplement to the literature review.

Stone dust passing a sieve sizes of 4.75 mm collected from the crushed stone dust was used. Concrete specimens having a grade of C-25 from normal strength produced by incorporating four different volume fractions of stone dust which are 0%, 30%, 50% and 70% by volume.

Initially, important tests will be conducted on the constituent material to determine the gradation and physical properties of river sand, stone dust and coarse aggregate, chemical composition and other characteristic of cement. After carrying out tests on the fresh concrete the specimens for the testing of mechanical properties in the hardened state will be prepared

by pouring the concrete into lubricated molds and the test on hardened concrete was carried out to check the residual compressive strength of the concrete after exposing it for elevated temperature and also the resistance of the concrete to chemical attack was evaluated by submerging it in to chemical solutions and testing for retained compressive strength and loss of weight. In addition, the water absorptions of all the samples were evaluated by weighting each sample before and after 7 and 28 days curing periods for both concretes with and without stone dust. The total of eight group of samples produced where each group contains four test sample series having different mix proportion. For each mix, three 150x150x150mm cubes were casted and the total number of 108 concrete cubes were produced.

The main parameters investigated in this study are the compressive strengths, workability and durability of the concrete and the test results were compared to that of conventional concrete.

The experimental program included the following:

- Test properties of constituent materials.
- Development of concrete mix of desired strength by making trials.
- Testing for the Workability of concrete mix.
- Casting and curing of specimens.
- Compressive strength test on concrete mix at the ages of 7 and 28 days after curing in water.
- Testing for durability
- After carrying out the tests the results obtained will be discussed and analysis will be made.
- Finally, conclusions will be made and recommendations for future studies will be forwarded.

1.6 Structure of the Research

The thesis is structured into five chapters and each chapter contains a number of sections and further subsections. A general introduction is provided along with the research objective, significance and methodology in the first chapter.

In Chapter Two a comprehensive review of concrete containing stone dust is presented. Under this topic the fundamentals of concrete made by partially replacing river sand with stone dust was discussed where the intensive review carried out on types and properties of stone dust, properties of fresh and hardened concrete which contains stone dust. Comparative analysis of conventional concrete and concrete made with stone dust also addressed by presenting the review on the previous research findings in this area.

Finally, in this chapter a general highlight on applications for stone dust in construction industry and economical evaluation of using stone dust to replace river sand was briefly addressed.

Chapter Three deals with the experimental study there by further discussing on program of the study, Materials used and Mix proportions, mixing, casting, and curing procedures are explained in detail. Procedures applied to perform related tests are also explained.

Results and discussions of the tests carried out during this study are covered in Chapter Four.

The conclusions are given in chapter Five together with recommendations for further research work. This will be followed by an extensive list of references. The Annexes A to F give the results of the individual tests, other relevant data and representative photos taken during the research work. This Data is presented in three different formats in this thesis. Graphs are used to show trends and to highlight possible relationships. Tables are used to present statistical analysis of the data collected.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 General

Concrete made by partially replacing sand with quarry dust is a composite material made of cements, fine aggregate, coarse aggregate, and quarry dust. It may also contain Pozzolana and admixtures commonly used with conventional concrete.

Rajapaksha et al., 2009 has observed that Properties of concrete composed with crushed stone dust in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. Quarry dust has particle sizes in the range of 0.05-5 mm and forms around 20-25% of the total output of rock crushing.

The mechanics of how the crushed stone dusts strengthen concrete or mortar, extending from the its resistance to loading under normal and elevated temperature and acidic environment exposed conditions is a continuing research topic. One approach to the mechanics of concrete containing crushed stone dust is to consider it as a composite material whose properties can be related to the stone dust properties (volume percentage, strength, water absorptions, workability and bonding parameter of the dust).

Recently some researchers have been devoted to the use of granite and lime stone dusts as partially or fully replacing of river sand in concrete. In particular, the concrete obtained by replacing sand with crushed stone dust evidenced a satisfactory improvement of the compressive strength, comparable tensile strength and a good durability property. As a consequence, concrete made with stone dusts from stone crushing sites appears a promising candidate for concrete production. As the different research finding shows the mechanical behavior of concrete composed with stone dusts is comparable to that of the conventional concrete made

with river sand. Therefore, it can be presumed that the facts presented about the fundamental principles, the properties of fresh and hardened concrete, mixing placing and finishing methods are also applicable for stone quarry dust containing concrete.

Many investigations have been conducted on utilization of quarry dust as total or partial replacement of river sand in concrete. At 28 days of curing, partial replacement of fine aggregate with 20- 50% quarry dust content resulted to optimum compressive strength of concrete for several mix ratios and water/cement ratios.

Some other researchers also suggested that the ideal percentage of replacement of sand with quarry dust can be between 55-75%. It was also suggested that 100% sand can also be replaced with quarry dust in presence and usage of fly ash.

But the recent investigations have shown that high amount adding of stone dust in concrete mix reduces the workability of the fresh concrete and recommends to introduce a new generation of additives such as super plasticizers.

According to M. Shukla and A K Sachan, 2000 workability of fresh concrete increased by the addition of Super plasticizer. For instance, the Workability of 40% replacement of stone dust with 2% Super plasticizer is equal to the workability of conventional concrete.

The addition of stone dust significantly improves many of the engineering properties of mortar and concrete.

The primary purpose of stone dust inclusion to concrete is to overcome the challenges of shortage in natural river sand in some areas and also environmental impact minimization of this material as there is high waste land fill with stone dust due to a large aggregate production requirement in construction industry.

Devi and Kannan, 2014 have investigated that Concrete containing quarry dust as fine aggregate can be effectively utilized in the construction industry with good quality materials, appropriate dosage of super plasticizer, appropriate mixing methods, and proper curing thereby ensuring sustainable development against environmental pollution.

This chapter is structured into nine major parts. Generally, it discusses about the fundamentals of both stone dust and the concrete that made with stone dust. First it discusses about the stone dust where types and properties of stone dust discussed.

Second the review was carried out on the concrete properties made by stone dust, comparative analysis with conventional concrete, Concrete production process. In addition, the factors affecting the stone dust concrete also discussed.

Finally, the review on economical evaluation of stone dust concrete and its practical applications briefly discussed.

2.2 Stone Dust

2.2.1 Types of stone dust

There are different types of stone dust available and it is mainly depending on the types of the stone by which it made. This is because stone dust is the byproduct of crushing stones. Therefore, the type of stone dust will depend on the type of stone that was being crushed to create the byproduct. Each of these different types of stone dust has different properties and they may come in different colors. Two of the most common types of stone dust are granite and limestone dusts. There are also differences in the types of stone dust available in terms of how fine or coarse they are.

This means that some stone dusts are superior due to their texture. According to Home Guides, the best type of stone dust to use for paving is crusher run, which is also known as processed gravel. It is superior to regular stone dust because it is coarse rather than powdery, it drains better, and it compacts well to form a stable base that is less likely to shift.

Manaseeh Joel, 2010 carried out his studies on the Suitability of Crushed granite fine (CGF) which is one type of stone dust to replace river sand in concrete production.

According to his study slump, compressive and indirect tensile strength tests were performed on fresh and hardened concrete. Twenty-eight days peak compressive and indirect tensile strength values of 40.70 N/mm² and 2.30 N/mm² respectively were obtained with the partial replacement of river sand with 20% CGF, as against values of 35.00N/mm² and 1.75N/mm² obtained with the use of river sand as fine aggregate. Based on economic analysis and results of tests, river sand replaced with 20% CGF is recommended for use in the production of concrete. Conservation of river sand in addition to better ways of disposing wastes from the quarry sites are some of the merits of using CGF.

2.2.2 Properties of stone dust

All materials have properties that make the suitable for different purposes. Stone dusts also has many properties that make it a useful byproduct to be used for landscaping jobs. Here below some important properties of this material to replace sand was identified by the researchers and presented.

Experimental results of M.G. Shaikh et al., 2014 suggest that the sharp edges of the particles in artificial sand provide better bond with the cement than the rounded part of the natural sand.

Chandana Sukesh, K. B., May 2013 studied on the specific gravity of both the materials i.e., sand and quarry dust and were found to be almost the same.

According to Vishal Agrawal et al., 2017 Quarry dust as a material is very much similar to sand in physical properties. As the research shows Sand obtained from the river beds and the quarry dust obtained from the quarries has almost equal specific gravity but have a large variation in the water absorption. The water absorption of quarry dust which was determined as 3.59% was very high due to which the concrete mix prepared with higher proportion of quarry dust has very low workability

Venkata Keerthi.B, J. Sudha Mani, 2017 investigated that Quarry stone dust has many of the useful properties of the stone that it comes from. It is very heat resistant and poses the problem of acute shortage in many areas. Some other properties found by different researchers to understanding the properties of stone dust which can help to decide for which jobs it is most suitable.

Some of these include:

- Flat and smooth- We can lay stone dust very flat and smooth to create an even and level surface for paving. This means there will no uneven surfaces in your garden.
- Low cost- In comparison to other options, such as sand, stone dust is usually a cheaper option. For many people, this gives it an advantage over other options as they can save money on their hardscaping project.

- Weed prevention- Using stone dust as filler between paving stones can solve the issue of weeds growing between paving stones. The properties of this material prevent this from happening, so it keeps paved area looking neat and tidy for longer.
- Non-porous-This is a non-porous material, and this gives stone dust an advantage for use between paving stones. It will stop water from heavy rain seeping below the paving stones into the base materials. Therefore, it can reduce the risk of shifting and damage to the paving stones.
- Variety- The exact properties of stone dust vary from one type to the next. You can choose from various grades, stone types, and colors.

Standards Organization of Nigeria, 2004 carried out the research on properties of the stone dust and some are the particle size distribution of river sand and quarry dust presented in Fig 2.1.as shown below.The values indicate that the river sand has a small range of particle size whereas the quarry dust has a wider range of particle sizes. Both aggregates fall into zone 2 of the grading requirements for fine aggregates and are suitable for producing concrete.

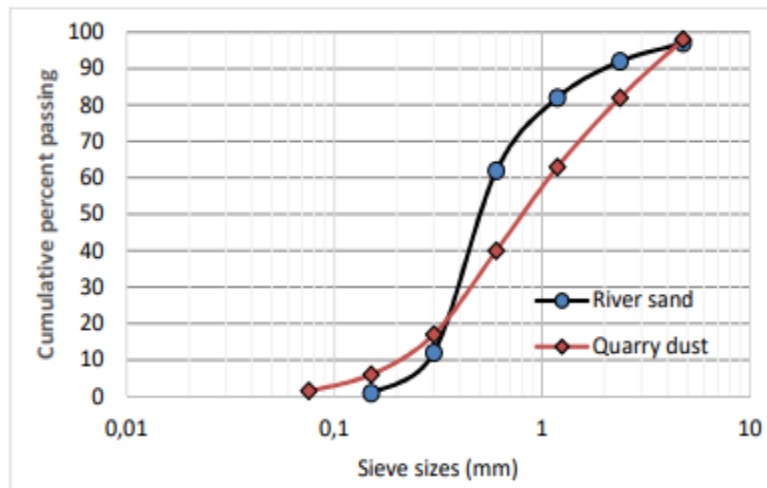


Figure 2.1: Particle size distribution of river sand and quarry dust

Anya, C.U. & Osadebe, N.N., 2015, and Eziefula, et.al. 2017 Carried out the study on the physical and mechanical properties of physical properties of the fine aggregates and physical and mechanical properties of the coarse aggregate. The values obtained for specific gravity of the aggregates were within the range for normal weight aggregates although quarry dust slightly exceeded the maximum limit stated in Neville and Brooks. The bulk densities of the river sand, quarry dust and granite are similar to values reported in previous investigations. Fineness modulus obtained for the fine aggregates indicate that river sand has relatively finer grains whereas quarry dust has coarse grains.

Table 2.1 Physical properties of sand and stone dust

S. No	Property	River sand	Quarry dust	Acceptable limit for concrete
1	Specific gravity	2.64	2.76	2.6-2.8
2	Fineness modulus	2.54	2.96	2.2-3.2
3	Density (Kg/m ³)	1570	1360	-

Table 2.2: Physical and mechanical properties of coarse aggregate

S. No	Property	Granite	Acceptance limit for concrete
1	Specific gravity	2.68	2.6-2.8
2	Density (Kg/m ³)	1545	-
3	Aggregate impact value (%)	15.1	25-45%
4	Los Angeles abrasion value (%)	18.3	30-40%

2.3 Properties of Concrete Containing Stone Dust

2.3.1 Property of freshly mixed concrete

Workability (Slump)

Dhir, R.K. & Jackson, N., 1996 have investigated that Quarry dust concrete and river sand concrete had slump values of 80 mm and 60 mm, respectively. Thus, fresh concrete mix of quarry dust concrete showed lower workability than river sand concrete for 1:2:4 mix ratio and water-cement ratio of 0.55. The higher slump observed for quarry dust may be due to higher sand content in quarry dust. Since the water content and cement content were constant, workability is expected to be lower in the concrete mix containing finer particles of fine aggregate. The quarry dust used in the study had higher percentage of coarse sand grains than river sand. Increase in fines content generally leads to lower slump if the water content remains the same. Finer particles have higher surface area which requires more amount of water for wetting. The slump of both quarry dust concrete and river sand concrete fell within the range of 25-100 mm, indicating medium workability.

The properties of Stone Dust Concrete in its freshly mixed state are influenced by the volume fraction of stone dust, sizes of stone dust, amount of water used and plasticizer used.

For conventionally placed stone dust composing concrete applications, adequate workability should be insured to allow placement, consolidation, and finishing with a minimum of effort, while providing uniform stone dust distribution and minimum segregation and bleeding. For a given mixture, the degree of consolidation influences the strength and other hardened material properties, as it does for plain concrete.

Chandana Sukesh, K. B., 2013 was concluded that the workability of the concrete mix decreases with the increase in percentage of quarry dust. It was suggested that the ideal percentage of replacement of sand with quarry dust can be between 55-75%. It was also suggested that 100% sand can also be replaced with quarry dust in presence of fly ash.

According to Brajesh Kumar Sumanthe slump values for different percentage of stone dust in concrete as shown in table 3. It indicates at a constant dose of super plasticizer (i.e., at 0.8% by weight of cement) the workability of concrete decreases rapidly with increment of stone dust in mixture. At high percentage level of stone dust, the slump is zero (i.e., no slump) due to more water absorption capacity of stone dust. So, for maintain workability the dose of super plasticizer was increased.

Table 2.3: Plasticizer dose at maintained slump

S. No	Sample Designation	Slump Value (mm) at Dose of Super Plasticizer 0.8% by Wt. of Cement	% Replacement with Stone Dust	% Dose of Super Plasticizer by Weight of Cement at which Slump Maintained 50 –75 mm
1	W0	100	0	0.6 (65mm)
2	W1	81	10	0.7 (70 mm)
3	W2	60	20	0.8 (60 mm)
4	W3	48	30	0.9 (54 mm)
5	W4	38	40	1.1 (60 mm)
6	W5	22	50	1.3 (52 mm)
7	W6	20	60	1.45 (55 mm)
8	W7	20	70	1.6 (58 mm)
9	W8	15	80	1.7 (51 mm)

2.3.2 Properties of hardened concrete

Rajaksha et al., 2009 have also used quarry dust as total replacement of sand in concrete. Quarry dust concrete at curing age of 28 days exhibited higher compressive strength than river sand concrete. However, Joel, M., 2010 and Manguriu et al, 2013 reported the lower compressive strength for quarry dust concrete in comparison with river sand concrete. The Reports on workability and density of quarry dust concrete are also varied.

According to K. Shyam Prakash¹ and Ch. Hanumantha Rao², 2016 the suitability of quarry dust as a sand replacement material shows that the mechanical properties are improved and also elastic modulus.

The study of P.M. Shanmugavadivu and R. Malathy, 2011 have shown that the permeability reduced with increase in proportion of manufactured sand. This may be due to less voids present in concrete with manufactured sand showing better bonding between the aggregate and cement paste.

Chandana Sukesh et al., 2013 have conducted an experimental study on the feasibility and suitability of the use of quarry dust for the partial replacement of sand in concrete. In the tenure of the study, the authors determined some important parametric properties of quarry dust. Also cubes for the partially replaced concrete of size 150mm x 150mm were casted, cured and then tested for the compressive strength. In this study the properties of concrete, consisting of sand partially replaced with quarry dust, like water absorption, specific gravity, workability etc. were determined. The study concluded that the replacement of sand with quarry dust led to an increase in the compressive strength of concrete samples.

I. Density

Neville, A.M. & Brooks, J.J. 2010 researched and found that the bulk density of normal weight concrete usually ranges from 2200–2600 kg/m³. According to his study the density of all the specimens fell within the range of normal weight concrete. The densities increase with curing age, with 7 days corresponding to the lowest density and 28 days attaining the highest density. There was an increase in 7.6% between the densities of the 7-day and 28-day curing age of river sand concrete. For the quarry dust concrete, the corresponding increase was 4.8%. The increase in the density is attributed to compaction effect of hydration process on the internal matrix of the concrete specimens owing to curing. The Fig. 2.2 shows the density results of river sand concrete and quarry dust concrete.

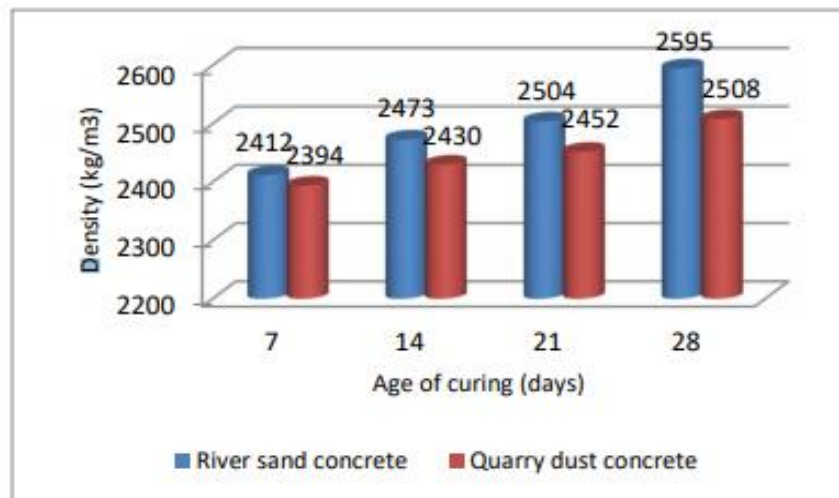


Figure 2.2: Compressive strength comparison for river sand and stone dust

According to British Standards Institution, 1997 River sand concrete attained higher densities than quarry dust concrete for all ages of curing. The higher density of river sand concrete can be as a result of higher density of the river sand in relation to the quarry dust. The density of river sand concrete and quarry dust concrete are within the nominal value of 24 kN/m^3 (i.e., $2,446 \text{ kg/m}^3$) for traditional normal weight concrete assumed in BS 8110-1. The density of 28-day river sand concrete and 28-day quarry dust concrete were higher than the value assumed by 6.1% and 2.5%, respectively. This implies that river sand concrete and quarry dust concrete would produce members with similar self-weight to traditional concrete.

I. Compressive Strength

Balamurugan, G. & Perumal, P., 2013 determined the trend in attainment of compressive strength of both river sand concrete and quarry dust concrete specimens and had similar compressive strength development with increase in age of curing, with river sand concrete having higher values of compressive strength for all curing ages. This is due to increased amount of hydration products with the longer curing age. The 7-day compressive strength for river sand concrete and quarry dust concrete were 68% and 65% of the 28-day compressive strength, respectively.

Chijioke et al., 2014 also obtained closer values on the respective ratio of the 7 day strength to 28 day strength in which used the same water-cement ratio and mix ratio. Factors which affect the strength attainment of concrete include aggregate grading and size, curing conditions and cement content.

According to Neville, A.M. & Brooks, J.J., 2010 the compressive strength of concrete at 7 days is usually within the range of 60-80% of the compressive strength at 28 days for conventional concrete cured under standard conditions.

For mixes intended to achieve 21 N/mm² target strength at 28 days, the compressive strength of river sand concrete exceeded the target strength by 36%. However, the compressive strength of the quarry dust concrete at 28 days of curing was less than the target strength by 12%. The lower compressive strength of quarry dust concrete could be attributed to the higher proportion of silt/clay particles in quarry dust compared with river sand. Presence of very fine particles in aggregate tends to interfere with the bond between cement paste and aggregate, which causes reduction in strength.

2.4 Stone Dust Concrete Versus Conventional Concrete

2.4.1 Strength of concrete

R.N. Misra, 1984) studied the water requirements and compressive strength of cement mortar using manufactured sand as FA, with FM ranging from 0.50 to 2.0 and 75% and 100% flow of mortar. Based on the above extensive experimental investigations, he had concluded that the strength of mortar with manufactured sand is higher than that of the corresponding mix with cement (sand) mortar. He has recommended the use of manufactured sand for mortar and has cautioned the removal of excessive proportions of very fine particles.

V.M. Malhotra, 1985 studies the performance of concrete, incorporating limestone dust (obtained from limestone quarries after crushing operations) as a partial replacement for natural sand in concrete.

Three series of concrete mixes with w/c ratio 0.70, 0.53 and 0.40 respectively, incorporating lime stone dust from 5-20% were prepared by direct replacement on an equivalent mass of recombined sand basis. The properties of fresh concrete i.e., slump, unit weight and air content (%) were determined. Compressive strength, freezing and thawing, drying and shrinkage, creep was determined for hardened concrete. They have concluded that incorporation of up to 10% limestone dust as a partial replacement for FA in concrete with w/c = 0.70 and 5% limestone dust in concrete with w/c = 0.53 does not significantly affect the properties of fresh and hardened concrete. However, there is considerable loss in slump, irrespective of w/c ratios, if lime stone dust is in excess of 10%.

Manasseh, 2010 investigated the suitability of Crushed Granite Fine (CGF) to replace river sand in concrete production for use in rigid pavement. Slump, compressive strength and indirect tensile strength tests were performed on fresh and hardened concrete. The 28-day peak compressive and indirect tensile strength values of 40.70 N/mm² and 2.30 N/mm² respectively, were obtained with the partial replacement of river sand with 20 per cent CGF, as against values of 35.00 N/mm² and 1.75 N/mm² obtained with the use of river sand as fine aggregate. Sivakumar et al., 2010) studied the 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) is higher than the controlled cement mortar cube. The 56 days maximum Compressive strength, split tensile strength and modulus of elasticity of concrete for 100% replacement of sand with quarry dust of 400 kg/m³ at F/C=0.6, was higher than the reference concrete.

M. Devi et al., 2011 carried out an investigation on strength and corrosion resistance behavior of inhibitors in concrete containing quarry dust as fine aggregate.

The incorporation of inhibitors as admixture did not show any adverse effects on the strength properties and there was an increase in strength up to certain percentage. The addition of inhibitors as admixture to concrete was found to lower the permeability and water absorption.

Lohani et al., 2012 studied the increase in dust content up to 30% increases compressive strength of concrete, if the dust content is more than 30% the compressive strength decreases gradually. But the compressive strength of quarry dust concrete continues to increase with age for all the percentage of quarry dust contents.

T. Shanmugapriya et al., 2012 carried out an investigation on optimization of partial replacement of M-sand by natural sand in high performance concrete with silica fume. It was reported that M-sand and silica fume increased the flexural and compressive strength.

2.4.2 Workability

T.S. Nagaraj et al., 1996 reported that rock dust due to its higher surface area consumes more cement in comparison to sand which increases workability. He studied to effect of rock dust and pebble as aggregate in cement and concrete and found that crushed stone dust could be used to replace the natural sand in concrete.

Hudson, 1999 reported that, “concrete manufactured with a high percentage of minus 75-micron material will yield a more cohesive mix than concrete made with typical natural sand”.

M. Shukla et al., 2000 studied environmental hazardous stone dust utilization in building construction. It is found that partial replacement will not affect the strength and also solve the problem of disposal of stone dust. The workability of concrete reduces with the increase in stone dust and this can be improved by adding suitable admixtures.

A.K. Sahu et al., 2004 investigated the basic properties of conventional concrete and concrete made using quarry dust have compared. They have studied M20 and M30 concretes. Equivalent mixes are obtained by replacing stone dust partially/fully. Test results indicate effective usage of stone dust with same compressive strength, comparable tensile strength and modulus of rupture. Workability of 40% replacement of stone dust with 2% Super plasticizer is equal to the workability of conventional concrete. Workability is increased by the addition of Super plasticizer.

Joseph O Ukpata et al., 2012 studied the workability of concrete using lateritic sand and quarry dust as fine aggregates was found to have the same trend with normal concrete. The density of hardened concrete using lateritic sand and quarry dust was found to range from 2293-2447 kg/m³.

Lohani et al., 2012 studied the slump value increases with increase in percentage replacement of sand with quarry dust.

M. Shukla and A K Sachan, 2000 studied environmental hazardous stone dust utilization in building construction. It is found that partial replacement will not affect the strength and also solve the problem of disposal of stone dust. The workability of concrete reduces with the increase in stone dust and this can be improved by adding suitable admixtures.

2.4.3 Durability

P.M. Shanmugavadiv et al. have shown from water permeability test that permeability reduced with increase in proportion of manufactured sand. This may be due to less voids present in concrete with manufactured sand showing better bonding between the aggregate and cement paste.

Results of rapid chloride penetration test shows that chloride ion penetrability is high for concrete with natural sand while it is reduced using manufactured sand. They attribute this due to coarser grain size of manufactured sand resulting in better packing of particles. They suggest that 70% of manufactured sand in concrete is the optimum replacement for natural sand for better results.

Experimental results of M.G. Shaikh et al., 2011 suggest that the sharp edges of the particles in artificial sand provide better bond with the cement than the rounded part of the natural sand. Both concrete made using artificial sand and natural sand are moderate to chloride permeability.

2.5 Mix Design Considerations for Concrete Made by Partially Replacing Sand with Stone Dust

Shukla et al., 1998 investigated the behavior of concrete made by partial or full replacement of river sand by crushed stone dust as fine aggregate and reported that 40 percent sand can be replaced by crushed stone dust without effecting the strength of concrete.

Venugopal et al., 1999 examined the effect of rock dust as fine aggregate in cement and concrete mixes. They have suggested a method to proportion the concrete using rock dust as fine aggregate.

R. Ilangovana et al., 2008 reported that the compressive strength, split tensile strength and flexural strength of concrete made with 40% or 50% replacement of sand with quarry dust is more than that made with other percentage of replacement Natural river sand, if replaced by hundred percent Quarry Dust from quarries, may sometimes give equal or better than the reference concrete made with Natural Sand, in terms of compressive and flexural strength.

A. Krishnamoorthi et al., 2010 reported that the 3- and 7-days cube compressive strength for concrete with 20% and 40% quarry dust is same as conventional concrete and with above 40% quarry dust the strength decreases subsequently. 28 days strength satisfies the target strength. The split tensile strength and flexural strength of concrete made with 40% of replacement of sand with quarry dust is more than that made with other percentage of replacement. The compressive strength of concrete made with 40% of quarry dust is more than that made with 0%, 20%, 50%, and 60% of quarry dust. Tensile strength of concrete made with 40% of quarry dust is more than that made with 0%, 20%, 50%, and 60% of quarry dust. Tensile strength of concrete made with 60% of quarry dust is more than that made with 0% of quarry dust.

Ganesha Mogaveera et al., 2011 studied the effect of Partial Replacement of Sand by Quarry dust in Plain Cement Concrete for different mix proportions. They have concluded that sand can be replaced effectively by means of quarry dust up to 20% to 25%.

K. Nagabhushana et al., 2011 studied the properties of mortar and concrete in which Crushed Rock Powder (CRP) was used as a partial and full replacement for natural sand. For mortar, CRP is replaced at percentages of 20, 40, 60, 80 and 100. The strength properties of concrete were investigated by replacing natural sand by CRP at replacement level of 20, 30, and 40 per cents.

Ganesha Mogaveera. G. Sarangapani and Anand V. R., 2011 have studied the effect of Partial Replacement of Sand by Quarry dust in Plain Cement Concrete for different mix proportions. They have concluded that sand can be replaced effectively by means of quarry dust up to 20% to 25%.

H. S. Sureshchandra et al., 2014 investigated that in the production of Hollow concrete blocks sand can be replaced partially (i.e., 50% replacement) by quarry dust instead of complete replacement. The blocks where 50% replacement is adopted performs better than blocks which are prepared conventionally using natural sand. Further admixtures can be used in the production of blocks for better performance. Hollow concrete blocks can be used in load bearing masonry structures.

Nagaraj T.S. et al. and Narasimahan et al., 1999 The mix design proposed the possibilities of ensuring the workability by wise combination of rock dust and sand, use of super plasticizer and optimum water content using generalized lyse Rule.

Sahu A.K. et al., 2009 reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by Quarry Rock Dust in concrete.

Ilangovan and Nagamani, 2000 reported that Natural Sand with Quarry Dust as full replacement in concrete as possible with proper treatment of Quarry Dust before utilization.

2.6 Mixing, Placing, Finishing and Curing of Concrete Made by Partially Replacing Sand with Stone Dust

2.6.1 Mixing

According to Devi and Kannan, 2011 Concrete containing quarry dust as fine aggregate can be effectively utilized in the construction industry with good quality materials, appropriate dosage of super plasticizer, appropriate mixing methods, and proper curing thereby ensuring sustainable development against environmental pollution.

2.6.2 Placing

Venkata Keerthi.B, J. Sudha Mani carried out an experimental work and includes casting and testing of specimens to know the compressive strength and flexural strength of cubes and beams. These concrete cubes and beams are casted and tested as per IS 516-1959 specifications.

The specimens are casted for the following: M25

M25 grade concrete with OPC+ Natural Sand

M25 grade concrete with OPC + Quarry Stone Dust

M40 grade concrete with OPC+ Natural Sand

M40 grade concrete with OPC + Quarry Stone Dust

2.6.3 Finishing

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of placing and mixing of concrete, air is likely to get entrapped in the concrete. If air is not removed fully, the concrete loses strength considerably.

Venkata Keerthi.B, J. Sudha Mani, 2017 used Table vibrator in order to achieve full compaction and maximum density is used in this experiment.

2.6.4 Curing and protection

Venkata Keerthi.B, J. Sudha Mani, 2017 follows the following procedures during their researches. After casting, the molded specimens are stored in laboratory at room temperature for 24 hours. After these periods the specimens were removed from the molds and immediately submerged in clean, fresh water curing tank. The specimens are cured for 7 days and 28 days.

2.7 Factors Affecting Properties of Concrete Containing Stone Dust

H. S. Sureshchandra, et.al. Conducted an extensive experimental study on the effect of replacement of Sand by Quarry dust in Hollow concrete blocks. During the tenure of the study the authors investigated different properties of quarry which play an important role in the mix design of concrete.

2.7.1 Volume of stone dust

According to some research investigations the slump of the concrete made by stone dust abruptly decreases by increasing the replacement level of sand.

M. Shukla and A K Sachan, 2000 studied environmental hazardous stone dust utilization in building construction. The workability of concrete reduces with the increase in stone dust and this can be improved by adding suitable admixtures.

Lohani et al., 2012 studied the increase in dust content up to 30% increases compressive strength of concrete, if the dust content is more than 30% the compressive strength decreases gradually.

It is found that 40% replacement of fine aggregate by quarry dust gives maximum result in strength than normal concrete and then decreases from 50%.

Results showed that by replacing 60% of fine aggregate with stone dust concrete of maximum compressive strength can be made as compared to all other replacement levels.

Slump(mm) of concrete made using stone dust decreases abruptly with increase in replacement level of river sand.

Celik et al., 1996 have reported that on increasing the dust content up to 10%, improved the compressive strength, flexural strength of concrete and drying shrinkage improved.

However, the dust content exceeding 10 % decreased the compressive strength, flexural strength and drying shrinkage gradually.

Chandana Sukesh, K. B., 2013 also concluded that the workability of the concrete mix decreases with the increase in percentage of quarry dust. It was suggested that the ideal percentage of replacement of sand with quarry dust can be between 55-75%. It was also suggested that 100% sand can also be replaced with quarry dust in presence and usage of fly ash.

H. S. Sureshchandra, et al. also conducted an extensive experimental study on the effect of replacement of Sand by Quarry dust in Hollow concrete blocks. Then different mix proportions for different percentage of quarry dust (50% and 100%) were tested under different water cement ratios also.

The study was concluded as, the production of Hollow concrete blocks sand can be replaced partially (i.e., 50% replacement).by quarry dust instead of complete replacement. The block where 50% replacement is adopted performs better than blocks which are prepared conventionally using natural sand. Further admixtures can be used in the production of blocks for better performance. Hollow concrete blocks can be used in load bearing masonry structures.

The study of BrajeshKumar Sumanshown that compressive strength of concrete made using stone dust as fine aggregate replacement having greater value in comparison of conventional concrete whereas the workability of concrete was decreased rapidly with the increment of stone dust in concrete. It may be due to the more water absorption capacity of stone dust in comparison of natural aggregate or lack of surface moisture in stone dust. So, a dose of super plasticizer was

used. But increment of stone dust also affected the workability of concrete which was maintained by different doses of super plasticizer.

2.7.2 Shapes of stone dust

Nimitha. Vijayaraghavan, Dr. A.S. Wayal found that, during the crushing process the manufactured sand have irregular shapes. Due to irregular shape of the aggregates, there is a better packing among the particles thereby reducing the voids in concrete.

Experimental results of M.G. Shaikh et al., 2011 suggest that the sharp edges of the particles in artificial sand provide better bond with the cement than the rounded part of the natural sand.

2.7.3 Workability and compaction of concrete

M.S. Shetty, 2013 found that the required slump could not be achieved by natural sand with given parameter of mix design. But with the use of manufactured sand with proper shape, surface texture, desirable grading to minimize void content, a highly workable mix with the given parameter of mix design, was achieved

2.7.4 Water cement ratio

According to K. Shyam Prakash (It is found that the strength of concrete is more for w/c of 0.45 when compared with w/c of 0.5. As the quantity of water increases, the compressive strength decreases when replaced with quarry dust. This is due to the water absorption property of quarry dust. It is well known that the w/c ratio increases as the strength decreases. But the observation regarding compressive strength of quarry dust when compared to sand is nonlinear.

2.7.5 Mixing of the concrete

2.8 Economic Evaluation of Concrete with Stone Dust

Manasseh, 2010 investigated that economic analysis and results of tests, river sand replaced with 20 per cent CGF is recommended for use in the production of concrete for use in rigid pavement. Conservation of river sand in addition to better ways of disposing wastes from the quarry sites are some of the merits of using CGF.

Radhikesh et al., 2010 investigated the cost of quarry dust much cheaper than that of the sand as such the proposal is also financially viable. This also reduces the burden of dumping crusher dust on earth and hence environmental pollution.

Hyginus E. Opara et al., 2018 studied that quarry dust as a material is very much similar to sand in physical properties and is very cheaply available as it is a waste by product from the extraction of aggregates. Cost of quarry dust is almost 10% of the cost of natural sand.

River sand is costly due to transportation, large scale depletion of resources and enforcement regulations. Quarry dust can be used as an alternative to the river sand. Cost analysis shows that there is 40% savings if quarry dust is used instead of sand.

Illangoan.R., 2000 has done a study on 100% replacement of sand by quarry dust in concrete. The compressive strength of concrete with quarry dust has 40% more strength than that of the concrete with sand.

Illangoan.R, 2000 studied on Cost analysis result and there is 40% savings if quarry dust is used instead of sand.

According to UNEP Global Environmental Alert Service, 2014 Sand and gravel represent the most widely consumed raw material on earth after water, and between 64-75% of aggregate mined each year is used for making concrete.

K. Shyam Prakash¹ and Ch. Hanumantha Rao², 2016 studied that The availability of sand at low cost as a fine aggregate in concrete is not suitable and that is the reason to search for an alternative material. Quarry dust satisfies the reason behind the alternative material as a substitute for sand at very low cost.

Nanda et al proposes that the stone dust can be replaced up to 50% without any effect on mechanical and physical properties and the economical saving will be 56% also as discussed by. According to Amit Kumar Singh et al, 2015 Stone dust can be used as an opposite substitute for fine aggregate in the case of non-availability of natural river sand at reasonable cost.

Mahzuz et al, 2011 has concluded that Stone dust is well appropriate in terms of strength and economy over normal sand for medium grade concrete.

Venkata Keerthi.B, J. Sudha Mani also investigated that Quarry rock dust can be an economic alternative to the river sand.

Quarry dust as a material is very much similar to sand in physical properties and is very cheaply available as it is a waste by product from the extraction of aggregates. Cost of quarry dust is almost 10% of the cost of natural sand.

According to Vishal Agrawal, et al. as the cost of quarry dust is very less in comparison to the current cost of sand due to its shortage, quarry dust can be seen as an effective and optimistic alternative for the replacement of sand in concrete.

2.9 Practical Applications of Concrete Made with Stone Dust

Manasseh, 2010 investigated the suitability of Crushed Granite Fine (CGF) to replace river sand in concrete production for use in rigid pavement. Slump, compressive strength and indirect tensile strength tests were performed on fresh and hardened concrete.

Sahu et al., 2009 concluded that adding 40% sand may be replaced by stone waste in concrete without compromising quality of concrete. It is used for different activities in the construction industries such as road construction, manufacture of building materials, bricks, tiles and autoclave blocks.

In their research Anya, C.U. & Osadebe, N.N., 2015, explained about practical application of quarry dust in construction industry and they found that only a little fraction of the quarry dust is used as filler in wearing courses of asphalt pavements.

In the production of Hollow concrete blocks sand can be replaced partially (i.e., 50% replacement).by quarry dust instead of complete replacement. The blocks where 50% replacement is adopted performs better than blocks which are prepared conventionally using natural sand.

H. S. Sureshchandra et al., 2014 studied that Further admixtures can be used in the production of blocks for better performance. Hollow concrete blocks can be used in load bearing masonry structures.

According to K. Shyam Prakash and Ch. Hanumantha Rao, 2016 Quarry dust has been used for different activities in the construction industry, such as building materials, road development materials, aggregates, bricks, and tiles.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Experimental Program

The main target of this study is to produce the concrete by partially replacing sand with crushed stone dust from quarry site and then to characterize its properties under different conditions, especially the strength and durability properties in the hardened state. A crushed stone dust collected from quarry site and passed through the sieve size of 4.75mm was used. The grade of C-25 concrete from Normal strength concrete were produced containing four different volume fractions which are 0% as a control mix, 30%, 50%, and 70% contents of stone dust.

As already discussed in the other chapters, the main factors controlling the mechanical performance of the obtained composite materials are the properties of the constituent materials, as well as the bond between them. For this reason, investigation of the properties of the constituent material and preliminary characterization of crushed stone dust was made to obtain their mechanical properties. The performances of unreinforced concrete were evaluated in order to better appreciate the improvement gained by the addition of stone dust.

Thereafter, the slump test and compressive strength at the age of 7- and 28-days curing was tested. Also, the durability of the concrete tested under different conditions there by the retained strength after exposing to high temperature, weight loss after chemical attacking and water absorption of the samples evaluated for each mix.

3.2 Materials

3.2.1 Cement

The cement used in all mixes was the locally manufactured Messebo PPC which was produced in accordance with EN 196 and BS 1370. Chemical compositions, physical, mechanical and other characteristic of the cement, as provided by the manufacturer, are presented in Table 3.1 and 3.2 [Source: Messebo Cement Factory, August 2009].

whereas the full data is attached in Annex F.

Table 3.1: Physical properties of cement

S. No	Physical and mechanical properties		(%)
1	Specific gravity (g/cm ³)		29.14
2	Specific surface area (cm ² /g)		5.91
3	Initial setting time (min)		6.76
4	Final setting time (min)		55.86
5	Soundness (mm)		1.52
6	Compressive strength (N/mm ²)	2 day	2.46
		28 day	0.01
7	Heat of hydration (Ki/Kg)	3 day	2.31
		28 day	25

Table 3.2: Chemical properties of cement

S. No	Chemical properties	(%)
1	SiO ₂	29.14
2	Al ₂ O ₃	5.91
3	CaO	6.76
4	MgO	55.86
5	SO ₃	1.52
6	Sulphur content	2.46
7	Chloride content	0.01
8	Los on Ignition (LOI)	2.31
9	Percentage of Pozzolana	25

3.2.2 Coarse aggregate

The coarse aggregate used for the preparation of the specimens was crushed basaltic stone with a maximum size of 19mm. It was brought from Aposto Construction crusher site, which is located at 45 km from Hawassa city. The aggregate was initially screened using different sieve size and then it was washed and dried and kept in the laboratory. Its bulk density and specific gravity were found to be about 1327.4 kg/m³ and 2.67 respectively.

Sieve analysis results and other characteristics of the aggregates are presented in Table 2.



Figure 3.1: Preparing coarse aggregate to test for its property

Table 3.3: Sieve analysis result of coarse aggregate

S. No	Sieves (mm)	Average retained mass (g)	Cumulative mass retained (g)	Cumulative Percentage mass retained (%)	Cumulative percentage finer by mass (%)	Specification limits	
						lower	upper
1	37.5	0	0	0	100	100	100
2	19	43.2	43.2	2.16	97.84	90	100
3	9.5	99.45	142.65	7.13	92.87	85	100
4	4.75	1909	1935	96.75	3.25	0	10
5	Pan	65	2000	100	0	0	0

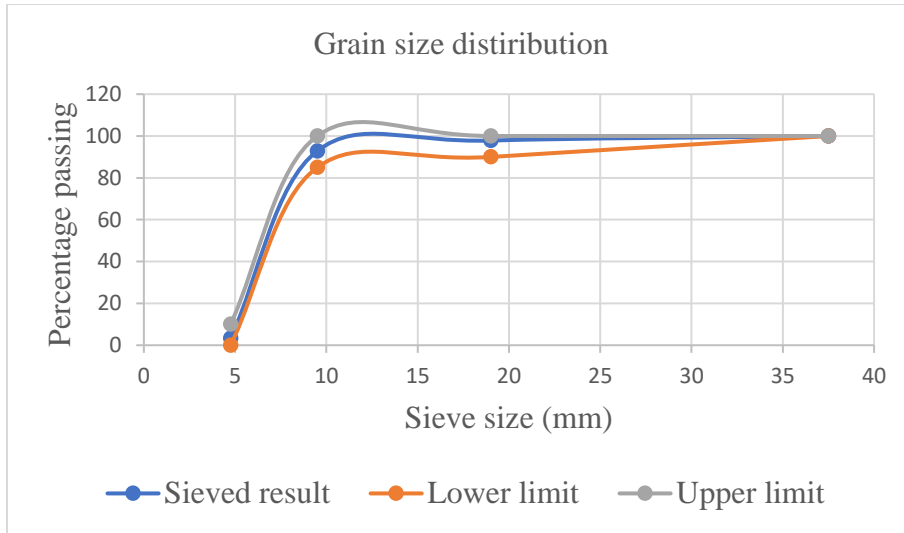


Figure 3.2: Grain size distribution of coarse aggregate

Summary of physical properties of coarse aggregate obtained from laboratory test following the ASTM standard are shown in the table below.

Table 3.4: Summary of physical properties of coarse aggregate

S. No	Physical properties	Values
1	Nominal aggregate size (mm)	37.5
2	Specific gravity	2.67
3	Bulk unit weight (kg/m ³)	1327.4
4	Absorption (%)	1.45
5	Moisture content (%)	0.68

3.2.3 Fine aggregate

The fine aggregate (river sand) used for this research work was brought from Dimtu which located at 42k. m from Hawassa. The silt content of the original sample was found to be 3.65% which is in the allowable limits.



Figure 3.3: Washing river sand



Figure 3.4: Preparing sand to test for physical properties

Table 3.5: Sieve analysis result of fine aggregate

S. No	Sieves (mm)	Average retained mass (kg)	Cumulative mass retained (kg)	Cumulative Percentage mass retained (%)	Cumulative percentage finer by mass (%)	Specification limits (Taken from sand)	
						Lower	Upper
1	9.5	0	0	0	100	98	100
2	4.75	9.19	9.19	2.30	97.70	95	100
3	2.36	41.97	51.16	12.79	87.21	80	100
4	1.18	81.84	133.00	33.25	66.75	50	85
5	0.6	82	215.00	53.75	46.25	25	65
6	0.3	71.95	286.95	71.74	28.26	5	30
7	0.15	66.3	353.25	88.31	11.69	0	10
8	Pan	45.75	400	100	0	0	0

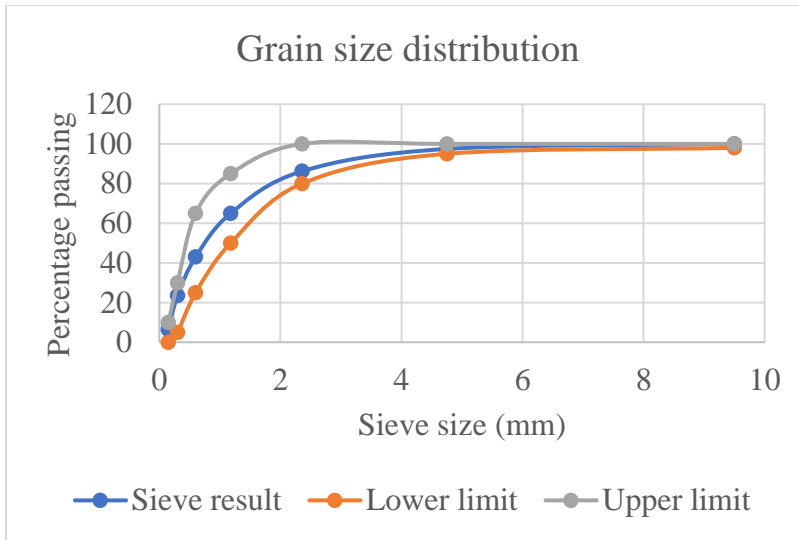


Figure 3.5: Grain size distribution of fine aggregate

Summary of physical properties of fine aggregate obtained from laboratory test following the ASTM standard is shown in the table below.

Table 3.6: Summaries of physical properties of fine aggregate

S. No	Physical properties	Values
1	Fineness modules, FM	2.62
2	Silt content (%)	3.65
3	Specific gravity	2.61
4	Bulk unit weight (kg/m ³)	1203
5	Absorption (%)	2.031
6	Moisture content (%)	1.69
7	Voids content (%)	43.52

3.2.4 Quarry dust

Quarry from Hawassa Monopol crushing site were collected and tested before using the same for the research program. The results obtained from quarry dust were compared with that of the sand. Table 3.7 shows the properties of quarry dust tested.



Figure 3.6: Preparing quarry dust for physical property test

Table 3.7: Sieve analysis results of quarry dust

S. No	Sieves (mm)	Average retained mass (kg)	Cumulative mass retained (kg)	Cumulative Percentage mass retained (%)	Cumulative percentage finer by mass (%)	Specification limits	
						lower	upper
1	9.5	0	0	0	100	98	100
2	4.75	6.42	6.42	1.60	98.40	95	100
3	2.36	38.1	44.52	11.13	88.87	80	100
4	1.18	89.73	134.25	33.56	66.44	50	85
5	0.6	85.75	220	55	45	25	65
6	0.3	114.77	334.77	83.70	16.31	5	30
7	0.15	40.48	375.25	93.81	6.19	0	10
8	Pan	24.75	400	100	0	0	0

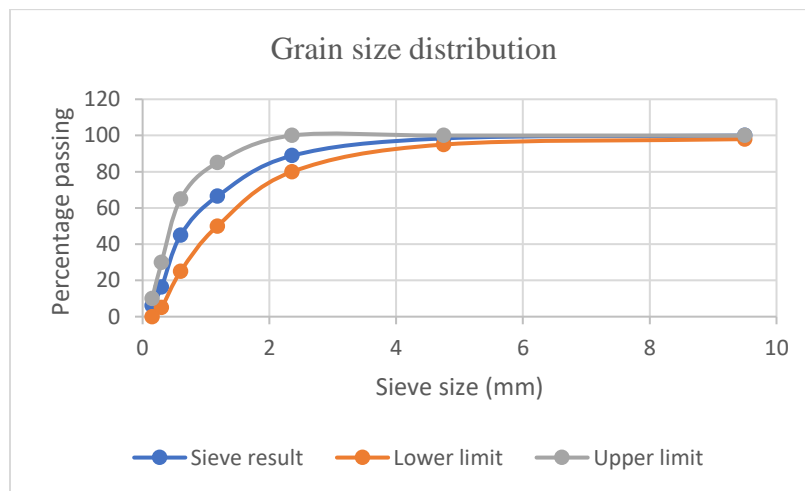


Figure 3.7: Grain size distribution of stone dust

Summary of physical properties of stone dust obtained from laboratory test following the ASTM standard is shown in the table 3.8 below.

Table 3.8: Summary of physical properties of stone dust

S. No	Physical properties	Values
1	Fineness modules, FM	2.79
2	Silt content (%)	3.92
3	Specific gravity	2.63
4	Bulk unit weight (kg/m ³)	1902
5	Absorption (%)	2.52
6	Moisture content (%)	1.32
7	Voids content (%)	45.15

3.2.5 Water

As the time-honored rule of the thumb for water quality is, “If you can drink it, you can make concrete with it”, potable water supplied by the municipality was used for all concrete mixes.

3.2.6 Chemical admixtures

To obtain sufficient consistency in the concrete mixes’ high-performance super plasticizing admixture with the commercial name Conplast SP 430 was used in all mixes. Conplast SP430 is a chloride free, superplasticising admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water.

Conplast SP430 conforms with BSEN 934-2, BS 5075 Part 3 and with ASTM C494 as Type A depending on dosage used. Conplast SP 430 has several advantages; some advantages among many worth mentioning are:

- Major increases in strength at early ages without increased cement contents are of particular benefit.
- Makes possible major reductions in water/cement ratio which allow the production of high strength concrete without excessive cement contents, and
- Increased workability levels are maintained for longer than with ordinary sulphonated melamine admixtures. Based on the product manual for high workability concrete the normal dosage range is from 0.70 to 2.00 liters/100 kg of cementitious material. In this research work 0.7 to 1% of admixture per cementitious material was used to attain the required workability in all mixes.

3.3 Sand Replacement Proportioning

Since there is no standard method of designing concrete mixes containing optimum proportion of stone dust as fine Aggregate, the method of mix design proposed for C25 of the Conventional Concrete mixes were first employed to design and finally natural sand was partially replaced by trial proportion of stone dust to obtain stone dust mixed concrete.

Concrete mixtures with different proportions of manufactured sand for natural sand ranging from 0% to 70% were casted.

The replacement proportion used for this study: -

- i. Concrete using 100% natural sand as fine aggregate.
- ii. Concrete using 30% quarry dust and 70% natural sand
- ii. Concrete using 50% natural sand and 50% quarry dust.
- ii. Concrete using 30% natural sand and 70% quarry dust.

Here below in Table 3.9 the proportions of fine aggregate and stone dust with the names of mixes that considered is presented.

Table 3.9: Proportion of sand and stone dust in each mix

S. No	Mix name	Proportion of sand (%)	Proportion of quarry dust (%)
1	A	100	0
2	B	70	30
3	C	50	50
4	D	30	70

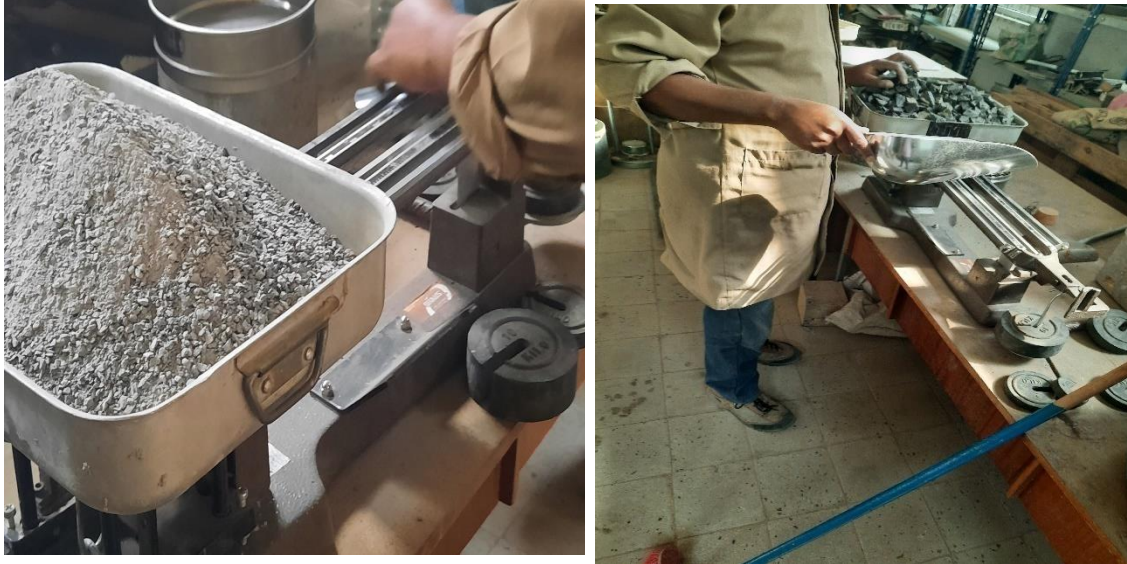


Figure 3.8: Sample material weighting

3.4 Mixing, Handling, Compaction and Curing of Concrete

The trial mix is prepared by varying the fine aggregate and crushed stone dust ratios and the total of 108 150x150x150mm concrete cubes and 4 slumps were prepared in the testing laboratory.

The mix is mixed thoroughly and the water is added as per the water binder ratio. To ensure the required slump values super plasticizer were added with the optimum proportions to get required workability of the concrete. The concrete is mixed in the mixer machine and filled in the concrete mold in three layers. Each layer compacted by 25 Manual strokes applied by 16 mm diameter rod. Figures 3.9 shows mixing, Fig. 3.11 shows casting and compacting of concrete.

After 24 h of casting the concrete specimen is removed from the mold then place the specimens in side of the curing tank filled with clean water. After 7 and 28 days, the test specimen is removed from the curing tank.



Figure 3.9: Mixing of concrete



Figure 3.10: Preparing of molds to cast concrete



Figure 3.11: Casting and compacting of concrete

3.5 Tests

Slump test was done for fresh concrete to check its workability. In hardened state the concrete tested for compressive strength after 7- and 28-days curing periods on both conventional and stone dust containing concrete.

In addition, the concrete was also tested for durability where the water absorption capacity, resistance to elevated temperature and marine environment attack was investigated after 28 days curing period.



Figure 3.12: Removing mold for slump test



Figure 3.13: Slump test



Figure 3.14: Preparing the concrete for compression strength test



Figure 3.15: Compression strength test



Figure 3.16 Burning of concrete cubes

3.6 Details of Experimental Works

3.6.1 Preparation of test specimens and testing procedure

The 150 mm sized concrete cubes were used as test specimens to carry out all the tests of hardened concrete cubes. The specimens were cast for C25 grade and the coarse aggregates of maximum sieve size 19 mm were used. The workability of fresh concrete was measured in terms of slump values.

To obtain the required slump value super plasticizer (0.7 to 1% of weight of cement) were added. The ingredients of concrete were thoroughly mixed in mixer machine till uniform consistency was achieved.

I. Preparation of test specimens

The test specimens were cast in steel molds. The inside of the molds was applied with oil for easy removal of mold. The solid ingredients were weighed on a digital balance and placed in pan mixer machine for mixing in dry condition. It was ensured that a uniform color of the mix was obtained before adding water. Water is added for correct quantity using measuring jar.

Proportioning of a concrete mix means determining the relative amounts of materials (cement, aggregates and water) required for batches of concrete of required strength. The investigation was carried out with standard mix C25 (1:2:3) with water cement ratio which varies from 0.45 to 0.55 where its increase is due to an increase in stone dust content of the concrete mix. This is done to know the possibilities of inclusion of quarry dust in optimum proportion in the ordinary construction activities using cement concrete.

a) Preparing mix design

As it was mentioned above there is no standard method of designing concrete mixes containing stone dust as fine aggregate, the method used was Conventional Concrete mixes design method and finally natural sand was partially replaced by quarry rock dust to obtain quarry stone dust concrete mixes.

Ethiopian Standard mix Proportion (by weight) used in the mixes of Conventional Concrete and Quarry Stone Dust concrete were fixed as 1:2:3 to attain C25 normal grade concrete properties.

The water/cement ratio for all mixes varies from 0.45 to 0.55 by weight.

Water reducing super plasticizers was used to improve the workability and its dose was fixed as 275 ml/50kg of cement.

The purpose of mix proportioning is to produce the required properties in both plastic and hardened concrete by working out a combination of available materials, with various economic and practical standards.

b) Preparation of marine environment

The marine environment was prepared by the major salts Sodium Chloride and Sodium Sulphate solution in an appropriate ratio to produce marine environment.

Deterioration studies in order to evaluate the degree of deterioration of three concrete mixes having different stone dust proportion against accelerated sulphate and chloride attack, concrete cube specimens were immersed in testing baths (one containing 7.5 percent NaCl and 7.5 percent Na₂SO₄ by weight of water. After 28 days of curing in these solutions the change in weight and

decrease in compressive strength with different mix proportions subjected to above solutions was determined.

c) Water absorption

The four different concrete mixes by varying the content of stone dust and river sand percentage one in the place of other were casted. All specimens were removed 24 hours after casting and subsequently water cured for 28 days. Then oven dried and again immersed in water three days then change in weight determined.

II. Testing procedures

Slump test for fresh concrete was conducted and the compression testing in hardened state of the concrete after 7 and 28 days of water curing is the basic test which conducted to analyze the strength of concrete.

In addition, durability test carried out for 28 days cured concrete where the samples tested for water absorption by immersion, weight loss and strength decrease after attacking in salt solutions and also strength reduction due to elevated temperature attack.

a) Slump test on fresh concrete

In slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. It is done based on ASTM C143, a sample of freshly mixed concrete is placed and compacted by rodding in the frustum of a cone shaped mould in three layers. Then the mould is raised vertically without twisting it and the concrete allowed to subside. The vertical distance between the original and displaced position of the centre of the top

surface of the concrete is measured and recorded as the slump of the concrete (ASTM C143/143M, 1900).

b) Compressive strength test on hardened concrete

The Compression test is conducted on 150 mm x 150 mm x 150 mm cube specimens which produced by using different proportion of stone dust used. The same concrete mix for which workability was determined is filled in to cubical moulds then compacted in three layers in order to remove entrapped air from freshly placed concrete and pack the aggregate particles together so as to increase the density of concrete and the specimens were cured for 7 and 28 days in water.

By compression testing machine of 200 kN capacity with load increment of 5 N/min after 7 and 28 days of curing periods the different series of the test samples placed on the cleaned lower bearing face of the test machine, the center of the machine is aligned with the axis of the specimens then the test is performed. Three test specimens were prepared for each selected stone dust proportion and tested for the strength of both cured ages of concrete.

The average of the three concrete cube specimens was considered and taken as the crushing strength of concrete. As per ASTM C39/39M, strength of any specimen varies by more than 15 percent of the average strength was rejected (ASTM C-39, 1901).

For this test, a total of 24 cubic specimens are prepared for conventional concrete as control mix and stone dust concrete as the detail is presented below.

Table 3.10: Total samples prepared for compression strength test after 7 days curing period

S. No	Name of sample	Percentage replacement	Curing period	Types of test	No of samples in each test
1	A	0	7	Compression test	3
2	B	30	7	Compression test	3
3	C	50	7	Compression test	3
4	D	70	7	Compression test	3
	Total number of samples				12

Table 3.11: Total sample prepared for compression strength test after 28 days curing period

S. No	Name of sample	Curing period (Days)	Types of test	Percentage replacement	No of samples in each replacement
1	A	28	Compression test	0	3
2	B	28	Compression test	30	3
3	C	28	Compression test	50	3
4	D	28	Compression test	70	3
Total number of samples					12

c) Elevated Temperature test

Forty-Eight, 150mm cube concrete specimens were casted and cured in water for 28 days. Afterwards, they were air-dried in the laboratory for 7 days and oven-dried for another 7 days. Finally, the specimens were exposed to high temperatures ranging from 200 to 800°C for 2 h. The heating rate was 1°C/min. After such a treatment, the specimens were allowed to cool with a rate of 1°C/min. Then, the specimens were stored in dry condition at room temperature for 7 days until testing.

Table 3.12: Total samples prepared for durability test at 600°C after 28 days curing period

S. No	Name of sample	Curing period	Types of test	Percentage of stone dust to replace sand	No of samples in each test
1	A	28	Durability Test	0	3
2	B	28	Durability Test	30	3
3	C	28	Durability Test	50	3
4	D	28	Durability Test	70	3
Total No of samples					12

Table 3.13: Total samples prepared for durability test at 800°C after 28 days curing period

S. No	Name of sample	Curing period	Types of test	Percentage of stone dust to replace sand	No of samples in each test
1	A	28	Durability Test	0	3
2	B	28	Durability Test	30	3
3	C	28	Durability Test	50	3
4	D	28	Durability Test	70	3
Total No of samples					12

The remaining (i.e., for 200 and 400°C temperatures) were prepared as the above each with total number of 12 samples and tested for durability.

d) Testing of the concrete for marine attacking

Under this, test resistance against external marine attack is evaluated both in weight and compressive strength losses. Cubes of size 150 x 150 x 150 mm were casted and cured in water for 28 days. Samples were taken out from water, cleaned with a cloth and initial weight is taken and compressive strength was evaluated for one set of specimens. Second sets of specimens were immersed in marine solution for a further curing period of 28 days. Properties such as Weight of the specimen and compressive strength of the specimen were recorded at the age of 28 days curing in the Na₂SO₄ and NaCl solution.

Weight of samples for all concrete mixes at the time of casting and after 15 cycles of alternate wetting and drying for all concrete mixes are determined.

Table 3.14: Total samples prepared for durability test by immersion in NaCl solution

S. No	Name of sample	Curing period	Types of test	Percentage to replace sand	No of samples in each test
1	A	7	Durability Test	0	3
2	B	7	Durability Test	30	3
3	C	7	Durability Test	50	3
4	D	7	Durability Test	70	3
Total No of samples					12

Table 3.15: Total samples prepared for durability test by immersion in Na₂SO₄ solution

S. No	Name of sample	Curing period	Types of test	Percentage to replace sand	No of samples in each test
1	A	7	Durability Test	0	3
2	B	7	Durability Test	30	3
3	C	7	Durability Test	50	3
4	D	7	Durability Test	70	3
Total No of samples					12

e) Water absorption test

Four different services of testing samples containing three concrete cubes of size 150mm for four different proportion of stone dust in mixes were casted. All specimens were removed 24 hours after casting and subsequently water cured for 28 days. The samples were oven dried for 48 hours to the final drying; the samples were immersed in water by suspending them by wire mesh. This test was done based on ASTM C 642 procedure (ASTM C-642, 1997). These samples stayed in water for three days till the difference between mass of two successive surface dried sample remain below 0.5% of large value. Then the final mass was measured. After having the final mass of oven dried the increase in weight in percentage of the original weight is expressed as its absorption and calculated as:

$$\text{Absorption } a, \% = \frac{(B - A) * 100}{(A)}$$

Where A=Mass of oven dried sample, g

B=Mass of surface dried sample in air after immersing, g



Figure 3.17: Immersion to test for water absorption

f) Marine attacking tests

Cubes of 150 mm from conventional and stone dust concrete were casted and cured in water for 28 days. After final days of curing, the specimens were removed from the water and the excess film of water on the surface was cleaned using standard preliminary surface cleaning process and weighed. Then the identified specimens were immersed in the marine solution. The solution was checked periodically. After the prescribed duration, the specimens were removed from the solution. Using weight loss method, percentage weight loss was determined. The process in each solution presented as follows: -

I. Sulphate attack

A solution of sodium sulphate was prepared by mixing 7.5% by weight of sodium sulphate (Na_2SO_4) with potable water. Then the cubes are cured in this solution for 28 days. After these curing days of exposure, the samples were taken out from the solution and the surfaces were dried with dry towel. Finally, the surface dried cubes were weighed and results are recorded to check for weight loss and also the retained compressive strength was checked by standard compression strength testing machine.

II. Chloride attack

A solution of sodium chloride (NaCl) was prepared by mixing 7.5% by weight of sodium chloride with potable water. After 28 days of exposure, the cubes were taken out and the surfaces were dried. Then final surface dried weights of cubes were found and checked for weight loss and also the retained compressive strength was checked by standard compression strength testing machine.

CHAPTER FOUR

4. TEST RESULTS AND DISCUSSION

4.1 Test Result of Fresh Concrete

4.1.1 Workability of concrete

Slump test on workability for the placing condition of concrete was conducted as per Ethiopian standard specification. Degree of workability maintained was low, that is, slump was maintained between 2 mm to 4 mm throughout the investigation by adding the required doses of super plasticizer by weight of cement, because of abrupt fall in slump with adding stone dust as gradual increase replacement of sand in concrete mix.

As the percentage replacement increases the slump height decreased resulting less workable concrete mixes. As the test results show, slump heights were checked and all slump values are slightly the same despite its increase by increasing percentage replacement of stone dust.

This was maintained by adding required dose of super plasticizer to keep an appropriate workability of the concrete there by protecting a high amount water and cement request of the mix as stone dust proportion increased.

An evaluated slump values with gradual increase percentage of stone dust as fine aggregate replacement in concrete are given in table 4.1. and shown graphically in Figure 4.1.

Table 4.1: Slump test results

S. No	Percentage Replacement	Slump values (mm)
1	0	40.00
2	30	37.50
3	50	35.60
4	70	34.50

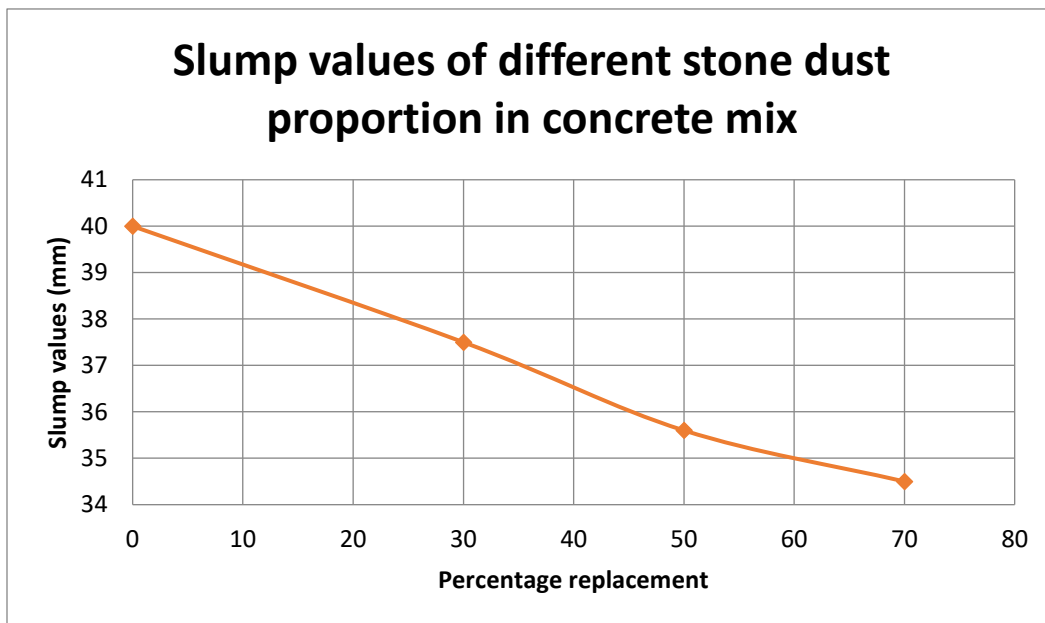


Figure 4.1 Slump value variations with increase in stone dust percentage

4.2 Test Results of Hardened Concrete

4.2.1 Compressive strength

The compressive strength test results of quarry dust concrete (cubes) were obtained in the first series immediately after curing in water for 7 days and 28 days and the results are presented in table 4.2 and 4.3 respectively.

a) For 7 days curing period

In this test, the compressive strength varies from 24.53 MPa to 30.20 MPa for 7 days curing as the stone dust content increases from 0 to 70%.

The compressive strength for this samples is minimum at 24.53 MPa for the concrete cubes produced by using the proportion 0 quarry dust and 100% river sand with 0.45 w/c ratio and it is maximum at 30.2MPa for the concrete cubes produced by using the 50% sand and 50% stone dust proportion. The other results vary with in the range of these two extremes according to their respective contents of stone dust and natural sand.

All the obtained results for 7-days curing period samples are presented in the table 4.2As the result shows concrete cubes with partial replacement of 50% sand by quarry dust perform better than cubes with other percentage replacement of sand. The slightly increase in the compressive strength observed until 50% replacement of sand and starts to decrease afterwards to 70% replacement. From the obtained results, the stone dust shows slightly exceeding in compressive strength of concrete than that of river sand.

Table 4.2: Compressive strength test results for 7 days curing period

S. No	Sample Name	Percentage of stone dust	Average Compressive strength (MPa)
1	A	0	24.53
2	B	30	28.52
3	C	50	30.2
4	D	70	27.92

b) For 28 days curing period

The same trends as 7 days curing period strength seen on the concrete cubes of 28 days curing period except the slight difference in strength due to concrete age.

In this series, the compressive strength varies from 27.62 MPa to 34.25 MPa for 28 days curing according to their contents in stone dust ranging from 0 to 70%.

The compressive strength for this samples is minimum at 27.62 MPa for the concrete cubes produced by using the 0 stone dust proportion 0.45 w/c ratio. The compressive strength is maximum at 34.25MPa for the concrete cubes produced by using the proportion using the 50% sand and 50% stone dust proportion.

All the obtained results for 28 days curing period samples are presented in the table 4.3. As the result shows, concrete cubes with partial replacement of 50% sand by quarry dust perform better than cubes with other percentage replacement of sand.

In general, as the result shows the slightly increase in the compressive strength observed until 50% replacement of sand and starts to decrease afterwards to 70% replacement.

Here also the concrete produced by partially replacing sand with stone dust shows better strength than the conventional concrete which fully mixed with river sand.

Table 4.3: Compressive strength test results for 28 days curing periods

S. No	Sample name	Percentage of stone dust	Average compressive strength (MPa)
1	A	0	27.62
2	B	30	31.56
3	C	50	34.25
4	D	70	30.83

Table 4.4: Comparison on the compressive strength test results of 7 days and 28 days curing periods

S. No	Sample Name	Percentage of stone dust	Average Compressive strength of cubes (MPa)	
			7 days	28 days
1	A	0	24.53	27.62
2	B	30	28.52	31.56
3	C	50	30.2	34.25
4	D	70	27.92	30.83

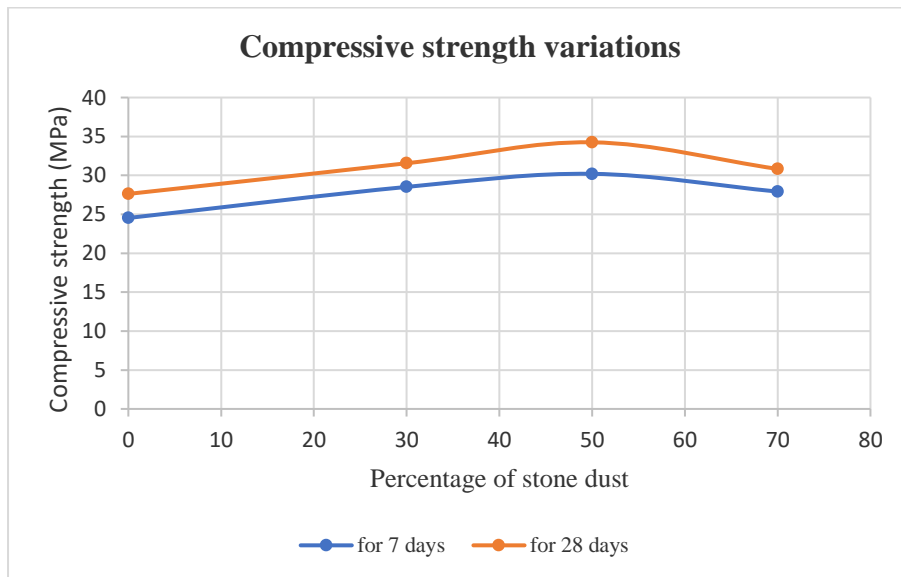


Figure 4.2: Compressive strength variations for 7 and 28 days curing periods

4.3 Durability Test Results

4.3.1 Water absorption by immersion

Water absorption of concrete is considered as one of the most important indicators for its quality and durability. The water absorption test results of concrete showed that, the percentage water absorption by weight increases as stone dust volume increases in concrete mix from 0% to 70% replacement. As the result shows concrete containing 30% stone dust performed well against water absorption. Also the concrete containing 0% stone dust have more water absorption capacity when compared to other proportion of the stone dust containing concrete.

Figure 4.3 presents the test results of water absorption by immersion, which indicates that the open porosity of concrete containing stone dust was slightly lower than of conventional concrete.

Table 4.5: Test results of water absorption of concrete

S. No	Mixture Designation	Percentage of stone dust	Curing (Days)	Water Absorption (%)
1	A	0	28	6.87
2	B	30		6.35
3	C	50		6.47
4	D	70		7.92

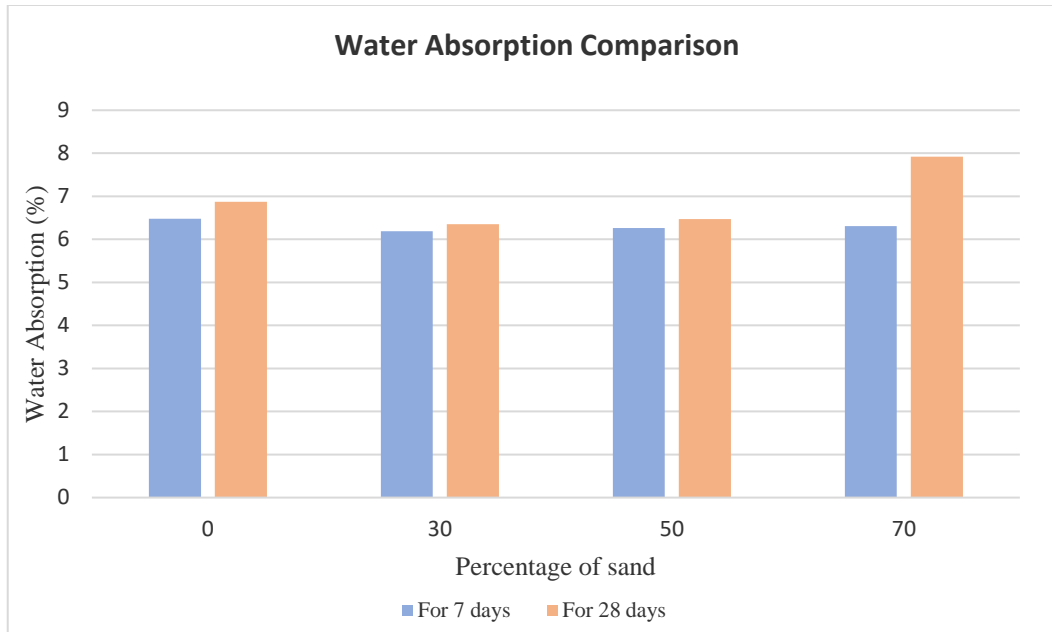


Figure 4.3: Concrete water absorption comparison

4.3.2 Test Results of Sulphate and chloride attacks

Sulphate and chloride attack test was conducted on the concrete containing different volume of stone dust. Parameters such as loss in weight and loss in compressive strength were tested after immersing the specimens in the solutions. From the results as the percentage of stone dust increases the resistance of concrete to sulphate attack increases. Both the weight loss and retained strength of all concrete cubes containing stone dust are lower than to that of river sand which shows the concrete with stone dust have better resistance than that of river sand concrete in marine environment.

Percentage loss of weight and compressive strength of stone dust specimens as compared to initial weight and the strength of controlled specimens are analyzed and presented in the following table 4.6 and figure 4.4.

Table 4.6: Test results of weight loss after 28 days attack in Na₂SO₄ solution

S. No	Sample Name	Stone dust dosage	Initial Weight (kg)	Wt. after 28 days (kg)	% wt. loss for 28 days acid curing
1	A	0	7.927	7.575	-4.44
2	B	30%	8.073	7.972	-1.25
3	C	50%	8.057	8.012	-0.55
4	D	70%	8.428	8.417	-0.13

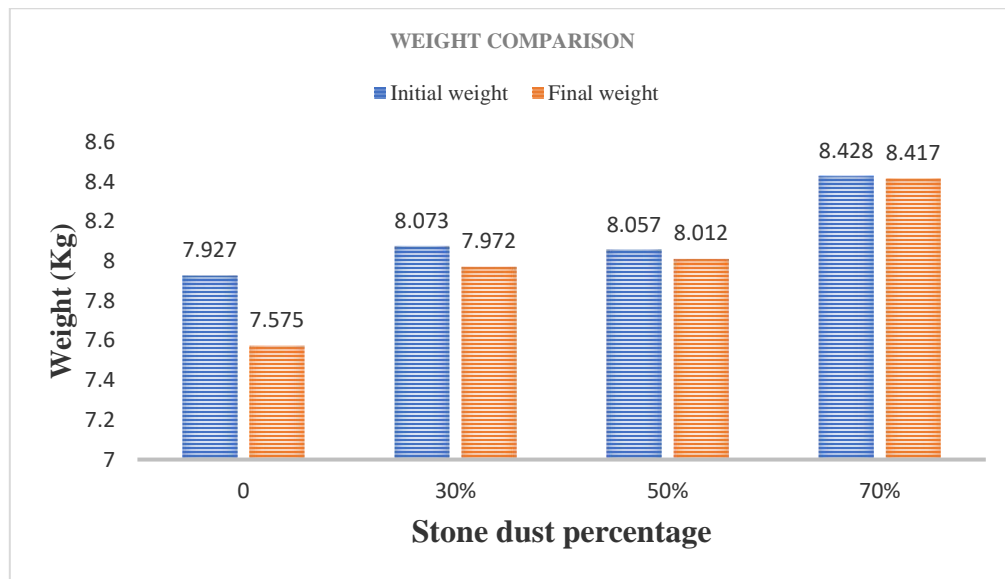


Figure 4.4: Comparison of weight loss of concrete in sulphate attack

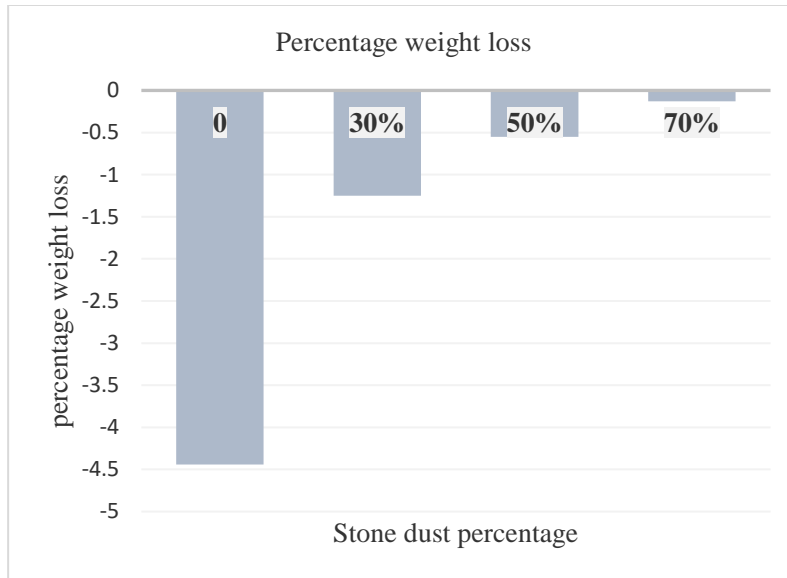


Figure 4.5: Percentage weight loss after sulphate attack

Table 4.7: Test Results of compressive strength loss after 28 days sulphate attack

S. No	Stone dust dosage	Compressive strength after 28 days of water curing	Compressive strength after 28 days of curing in acidic water	% loss in compressive strength for 28 days acid curing
1	0	27.62	25.396	-8.05
2	30%	31.56	29.982	-4.98
3	50%	34.25	29.691	-13.31
4	70%	30.83	24.340	-21.05

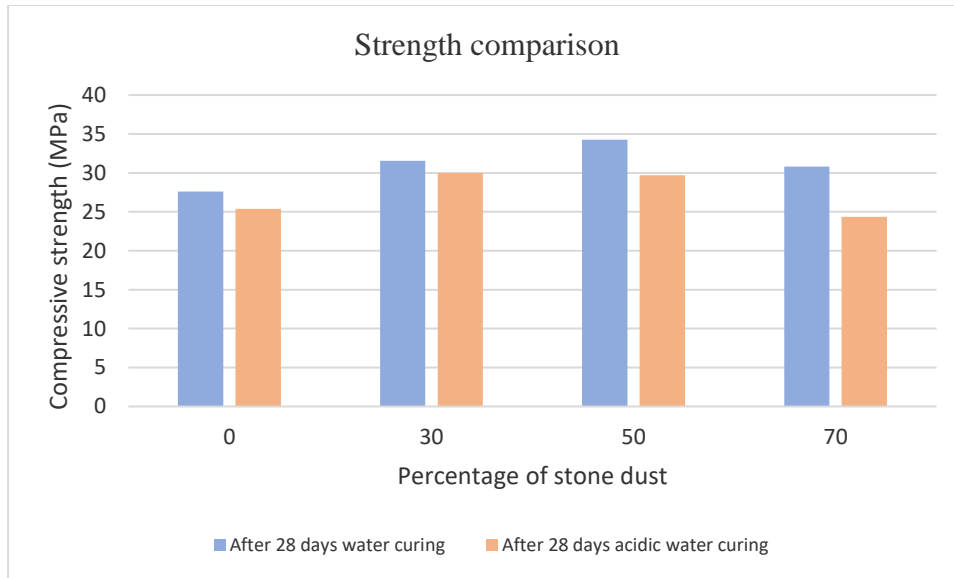


Figure 4.6: Compressive strength comparison after Na₂SO₄ attack

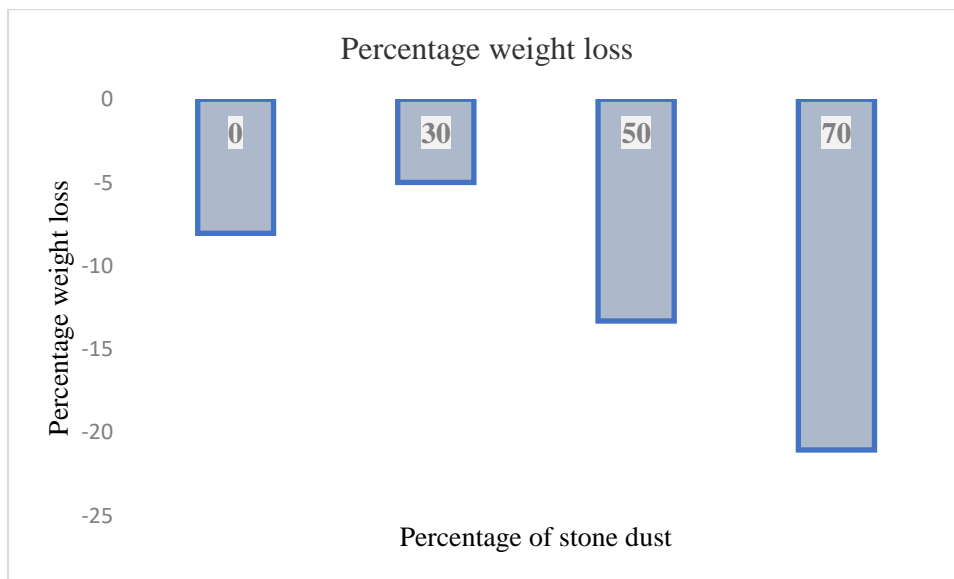


Figure 4.7: Compressive strength loss after Na₂SO₄ attack

Table 4.8: Weight loss after HCl attack

S. No	Sample Name	Stone dust dosage	Initial Weight (kg)	Wt. after 28 days (kg)	% wt. loss for 28 days acid curing
1	A	0	7.927	7.364	-7.102
2	B	30%	8.073	7.891	-2.25
3	C	50%	8.057	7.981	-0.943
4	D	70%	8.428	8.413	-0.1755

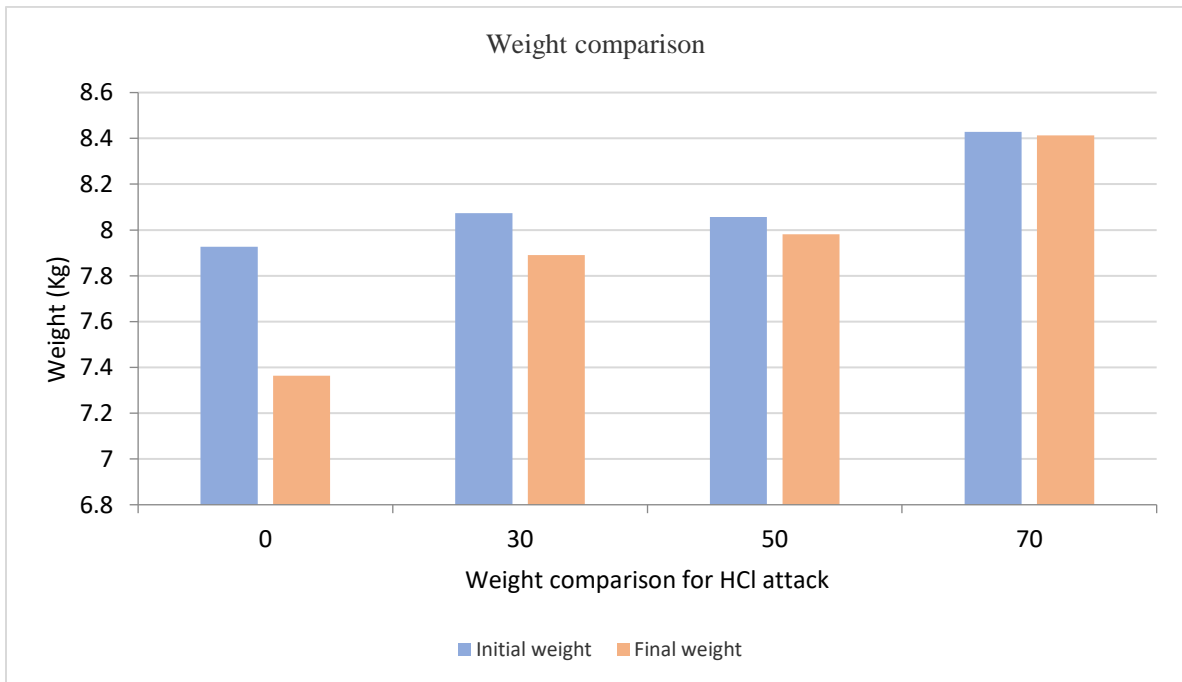


Figure 4.8: Weight loss comparison after HCl attack

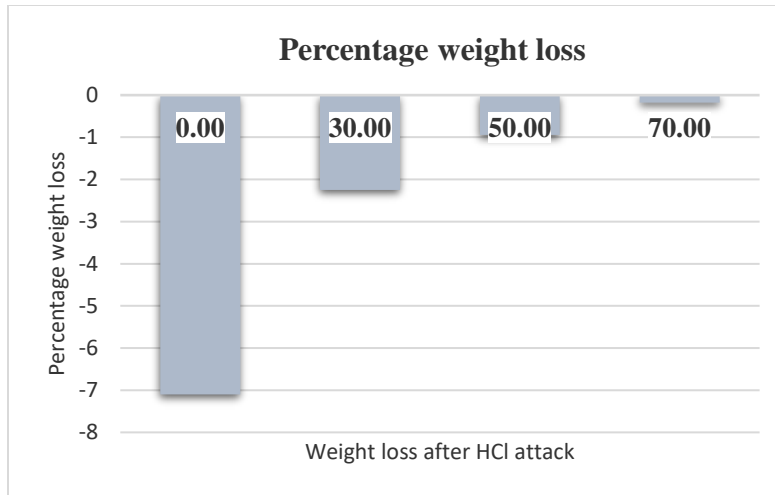


Figure 2.9: Percentage weight loss after HCl attack

Table 4.9 Compressive strength loss after HCl solution attack

S. No	Stone dust dosage	Compressive strength after 28 days of water curing	Compressive strength after 28 days of curing in acidic water	% loss in compressive strength for 28 days acid curing
1	0	27.62	24.062	-12.88
2	30%	31.56	28.73	-8.96
3	50%	34.25	26.50	-22.62
4	70%	30.83	22.071	-28.41

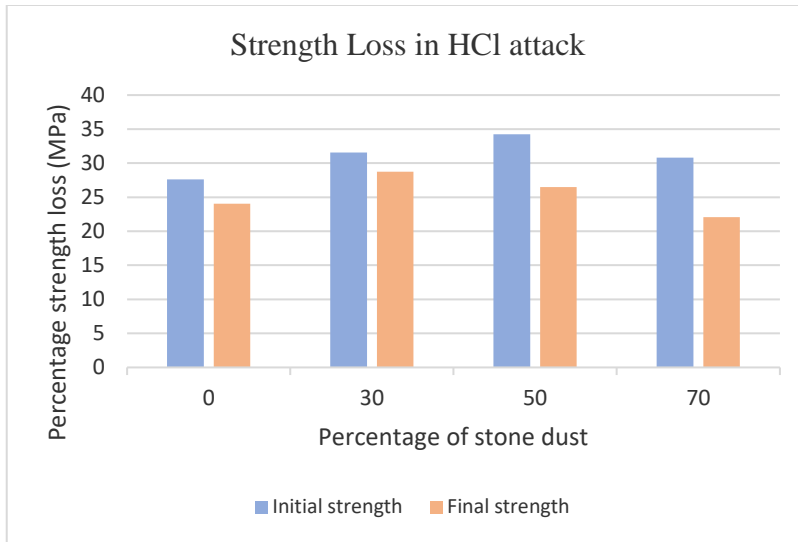


Figure 4.10: Compressive Strength comparison after HCl attack

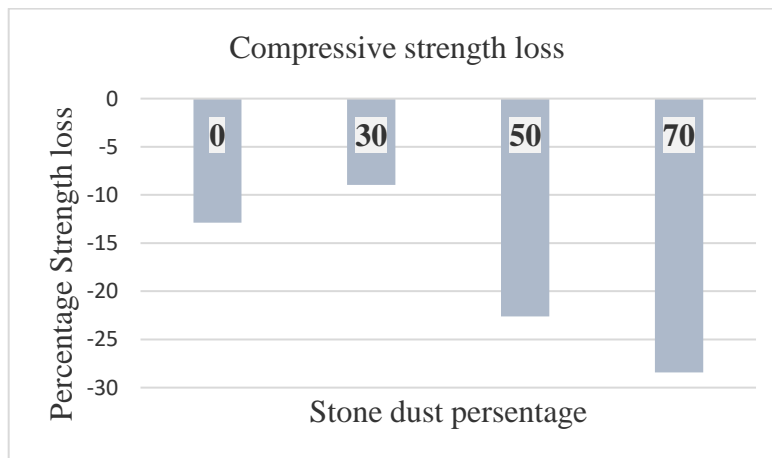


Figure 4.11: Strength loss after HCl attack

4.3.3 Test results after elevated temperature exposure

The retained properties of concrete after such exposures are still of great importance in terms of the serviceability of structures.

In this research I found that the main effects of elevated temperatures on concrete structures was the reduction in compressive strength of concrete and retained compressive strength values after exposure to elevated temperatures are presented in Table 4.6 and Figure 4.7.

The retained compressive strength was calculated as the percent compressive strength of concrete after exposure with respect to strength of unheated specimen.

The test results revealed that the retained compressive strength significantly decreased with an increase in exposure temperature.

It slightly reduced upon heating at 400°C and there was a sharp reduction beyond that point.

It was found that the concrete lost its strength significantly at the temperature range between 400 and 800°C.

When the comparison made between conventional concrete and stone dust concrete the strength retained for conventional concrete is less than to that of stone dust concrete with all proportion of stone dust considered in this research and has better resistance to the fire.

Table 4.10: Test results of retained strength after the concrete exposed to elevated temperature

S. No	Mix Name	Percentage of stone dust	Sample Curing period (Days)	Temperature level (°C)	Compressive strength (MPa)
1	A	0	28	0	27.62
				200	26.7914
				400	23.477
				600	11.600
				800	2.762
2	B	30	28	0	31.56
				200	30.613
				400	26.826
				600	13.255
				800	3.156
3	C	50	28	0	34.25
				200	33.222
				400	29.112
				600	14.38
				800	3.425
4	D	70	28	0	30.83
				200	29.905
				400	26.206
				600	12.949
				800	3.083

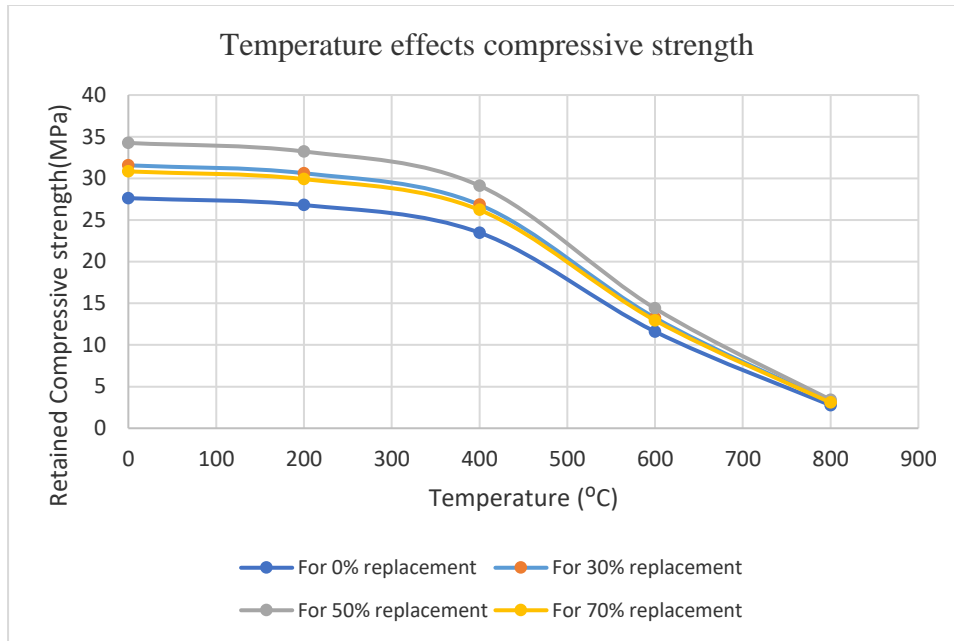


Figure 4.12: Comparison of temperature effects

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions drawn from the present study: -

1. Workability of the concrete in fresh state decreases with an increase of stone dust proportion by volume in concrete mix and this can be minimized by optimum use of plasticizer.
2. Slightly increase in compressive strength of the concrete with partial replacement of sand with stone dust to 50% Quarry Rock Dust from quarries was detected in this research and give better than the reference concrete made with Natural Sand and other proportions of stone dust, in terms of compressive strength.
3. Studies reported here have shown that the strength of Quarry Rock Dust concrete is comparatively 12.7-23.5 percent more than that of similar mix of Conventional Concrete.
4. The Durability of Quarry Rock Dust concrete under elevated temperature, sulphate and chloride action is higher than to the Conventional Concrete. The water absorption of Quarry Rock Dust concrete is slightly lower than Conventional Concrete. Therefore, the results of this study provide a strong support for the use of Quarry Rock Dust as fine aggregate in Concrete manufacturing.
5. Thus, it can be concluded that the replacement of natural sand with Quarry Rock Dust, as partial replacement in concrete is possible.

5.2 Recommendations

Based on the investigation made the following recommendations are forwarded for studies in purpose of future excellence.

1. The interesting results confirm the promising application of stone dust in concrete. However, further research work is still necessary in order to have a more in-depth understanding of the material properties and to evaluate possible practical applications. And also, economic evaluation of the adoption of currently available stone dust.
2. In evaluation of fresh concrete workability, the slump test is inadequate and cannot satisfactorily distinguish the effects of stone dust inclusion on the consistency of stone dust concrete. Methods employing dynamic consolidation such as inverted slump cone test or Vebe test should be used in order to attain a clearer view of the effects of stone dust inclusion.
3. It is also advisable to carry out more trial casting with Quarry Rock Dust in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement.

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APPENDECES

Appendix: A

Compressive Strength Test Results

Table A-1: 7th day compressive strength test results

S. No	Name of sample	Cube Name	Dimensions (cm)			Weight (g)	Volume (cm ³)	Unit weight in (g/cm ³)	Failure Load (kN)	Compressive Strength (MPa)
			L	W	H					
1	A	A-1	14.96	15.28	14.98	7910.00	3424.26	2.31	530.10	23.56
		A-2	15.12	15	15.09	7950.00	3422.41	2.32	561.60	24.96
		A-3	14.92	15.24	15.1	7920.00	3433.45	2.31	564.30	25.08
		Average				7926.67	3426.71	2.31	552.00	24.53
2	B	B-1	15	15.23	15.28	8030.00	3490.72	2.30	642.83	28.57
		B-2	14.98	14.96	15.24	8160.00	3415.30	2.39	629.10	27.96
		B-3	15.12	15.15	15.96	8030.00	3655.93	2.20	653.40	29.04
		Average				8073.33	3520.65	2.30	1377.78	28.52
3	C	C-1	14.95	15.08	15.14	8070.00	3413.25	2.36	699.08	31.07
		C-2	14.96	14.97	15.28	8060.00	3421.97	2.36	678.38	30.15
		C-3	15.13	15.18	15	8040.00	3445.10	2.33	664.65	29.54
		Average				24170.00	10280.33	2.35	680.70	30.25
4	D	D-1	15.28	15.26	15.14	8030.00	3530.24	2.27	613.13	27.25
		D-2	15.19	15.07	15.03	8160.00	3440.57	2.37	621.23	27.61
		D-3	15.02	14.96	15.09	8030.00	3390.71	2.37	650.03	28.89
		Average				8073.33	3453.84	2.34	628.13	27.92

Table A-2: 28th days compressive strength test result

S. No	Name of sample	Cube Name	percentage of stone dust	Dimensions (cm)			Weight (g)	Volume (cm ³)	Unit weight in (g/cm ³)	Failure Load (kN)	Compressive Strength (MPa)
				L	W	H					
1	A	A-1	0	14.96	15.28	14.98	8090	3424.26	2.36	614.7	27.32
		A-2		15.12	15	15.09	8130	3422.41	2.38	599.4	26.64
		A-3		14.92	15.24	15.1	8120	3433.45	2.36	650.25	28.9
Average							8113.33	3426.71	2.37	621.45	27.62
2	B	B-1	30	15	15.23	15.28	8180	3490.72	2.34	717.975	31.91
		B-2		14.98	14.96	15.24	8060	3415.30	2.36	689.4	30.64
		B-3		15.12	15.15	15.96	8230	3655.93	2.25	723.15	32.14
Average							8156.67	3520.65	2.32	710.175	31.56
3	C	C-1	50	14.95	15.08	15.14	8260	3413.25	2.42	773.1	34.36
		C-2		14.96	14.97	15.28	8250	3421.97	2.41	775.125	34.45
		C-3		15.13	15.18	15	8230	3445.10	2.39	763.875	33.95
Average							8246.67	10280.33	2.41	770.7	34.25
4	D	D-1	70	15.28	15.26	15.14	8190	3530.24	2.32	710.1	31.56
		D-2		15.19	15.07	15.03	8320	3440.57	2.42	673.2	29.92
		D-3		15.02	14.96	15.09	8180	3390.71	2.41	697.95	31.02
Average							8230	3453.84	2.38	693.75	30.83

Appendix: B

Retained Compressive Strength Test Results After Elevated Temperature Exposure

Table B-1: Retained compressive strength after 200° C temperature exposure

Retained compressive strength at 200° C					
S. No	Name of sample	Cube Name	percentage of stone dust	Failure Load (kN)	Retained Compressive Strength (MPa)
1	A-T-200	A-1-T200	0	605.199	26.85
		A-2-T200		597.9462	26.54
		A-3-T200		607.77	27
Average				603.6384	26.79
2	B-T-200	B-1-T200	30	681.461	30.22
		B-2-T200		674.6992	29.96
		B-3-T200		714.024	31.65
Average				690.0614	30.61
3	C-T-200	C-1-T200	50	745.27299	33.11
		C-2-T200		674.0976	29.92
		C-3-T200		758.2456	33.64
Average				750.8172	33.22
4	D-T-200	D-1-T200	70	672.975	29.91
		D-2-T200		668.2272	29.62
		D-3-T200		680.6313	30.21
Average				673.9445	29.91

Table B-2: Retained compressive strength at 400° C

Retained compressive strength at 400° C					
S. No	Name of sample	Cube Name	percentage of stone dust	Failure Load (kN)	Retained Compressive Strength (MPa)
1	A-T-400	A-1-T400	0	530.1105	23.55
		A-2-T400		535.95	23.82
		A-3-T400		519.9924	23.08
Average				528.684	23.48
2	B-T-400	B-1-T400	30	597.4556	26.53
		B-2-T400		607.6784	26.96
		B-3-T400		607.725	27.01
Average				604.286	26.83
3	C-T-400	C-1-T400	50	668.3936	29.68
		C-2-T400		655.9414	29.14
		C-3-T400		641.7	28.52
Average				655.345	29.11
4	D-T-400	D-1-T400	70	711.3624	31.56
		D-2-T400		673.4992	29.92
		D-3-T400		698.5704	31.02
Average				694.477	26.21

Table B-3: Retained compressive strength at 600° C

Retained compressive strength at 600° C					
S. No	Name of sample	Cube Name	percentage of stone dust	Failure Load (kN)	Retained Compressive Strength (MPa)
1	A-T-600	A-1-T600	0	250.3112	11.12
		A-2-T600		263.0336	11.68
		A-3-T600		270.225	12.01
Average				261.189	11.60
2	B-T-600	B-1-T600	30	295.4624	13.12
		B-2-T600		303.0285	13.45
		B-3-T600		297.45	13.22
Average				298.646	13.26
3	C-T-600	C-1-T600	50	325.703	14.45
		C-2-T600		322.55397	14.33
		C-3-T600		323.0185	14.35
Average				323.758	14.38
4	D-T-600	D-1-T600	70	298.39	13.25
		D-2-T600		289.90304	12.88
		D-3-T600		286.5523	12.73
Average				291.615	12.95

Table B-4: Retained compressive strength after 800° C Temperature exposure

Retained compressive strength at 800° C					
S. No	Name of sample	Cube Name	percentage of stone dust	Failure Load (kN)	Retained Compressive Strength (MPa)
1	A-T-800	A-1-T800	0	65.2703	2.9
		A-2-T800		61.67192	2.74
		A-3-T800		59.41848	2.64
Average				62.1202	2.76
2	B-T-800	B-1-T800	30	70.875	3.15
		B-2-T800		69.54354	3.09
		B-3-T800		73.14125	3.25
Average				71.1866	3.16
3	C-T-800	C-1-T800	50	77.20244	3.43
		C-2-T800		76.75569	3.41
		C-3-T800		77.86384	3.46
Average				77.274	3.43
4	D-T-800	D-1-T800	70	69.99988	3.11
		D-2-T800		69.09342	3.07
		D-3-T800		68.6433	3.05
Average				69.2455	3.08

Appendix: C

Test Results of Weight Loss After Chemical Attack

Table C-1: Weight loss after 28 days sulphatic solution attack

Weight loss after 28 days sulphate attack						
S. No	Name of sample	Cube Name	percentage of stone dust	Initial Weight	Wt. after 28 days (kg)	% wt. loss for 28 days acid curing
1	A-S-W	A-1-S1-W1	0	7.927	7.660	
		A-2-S2-W2		7.926	7.500	
		A-3-S3-W3		7.928	7.566	
Average				7.927	7.575	-4.44
2	B-S-W	B-1-S1-W1	30	8.072	7.975	
		B-2-S2-W2		8.073	7.971	
		B-3-S3-W3		8.074	7.970	
Average				8.073	7.972	-1.25
3	C-S-W	C-1-S1-W1	50	8.055	8.018	
		C-2-S2-W2		8.06	8.010	
		C-3-S3-W3		8.056	8.008	
Average				8.057	8.012	-0.55
4	D-S-W	D-1-S1-W1	70	8.43	8.420	
		D-2-S2-W2		8.428	8.419	
		D-3-S3-W3		8.426	8.413	
Average				8.428	8.417	-0.13

Appendix: D

Test Results of Compressive Strength Loss After Sulphate Attacks

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Table D-1: Compressive strength loss after 28 days sulphate attack

Compressive strength after 28 days sulphate attack						
S. No	Name of sample	Cube Name	percentage of stone dust	Compression strength after 28 days water curing	Compression strength after 28 days acidic curing	% compression strength loss
1	A-S-C	A-1-S1-C1	0	27.650	25.410	-8.10
		A-2-S2-C2		27.570	25.390	-7.91
		A-3-S3-C3		27.640	25.388	-8.15
Average				27.62	25.396	-8.05
2	B-S-C	B-1-S1-C1	30	31.61	29.987	-5.13
		B-2-S2-C2		31.55	29.985	-4.96
		B-3-S3-C3		31.52	29.975	-4.90
Average				31.56	29.982	-5.00
3	C-S-C	C-1-S1-C1	50	34.28	29.698	-13.37
		C-2-S2-C2		34.23	29.686	-13.27
		C-3-S3-C3		34.25	29.688	-13.32
Average				34.25	29.691	-13.31
4	D-S-C	D-1-S1-C1	70	30.82	24.350	-20.99
		D-2-S2-C2		30.94	24.330	-21.36
		D-3-S3-C3		30.73	24.341	-20.79
Average				30.83	24.340	-21.05

Appendix: E

Photographic Presentation



Figure AN. E-1: Coarse aggregate deposited on crushing site



Figure AN. E-2: Stone dust at crushing site



Figure AN. E-3: sieving of stone dust



Figure AN. E-4: Aggregate washing



Figure AN. E-5: Washing of sand



Figure AN. E-6: River sand and stone dust to determine specific gravity



Figure AN. E-7: Weighting pycnometer



Figure AN. E-8: Aggregate weighting



Figure AN. E-9: Weighting river sand



Figure AN. E-10: Weighting stone dust



Figure AN. E-11: oven drying (River sand, Stone dust and coarse aggregate)



Figure AN. E-12: Concrete mixing



Figure AN. E-13: Preparing for slump test



Figure AN. E-14: Concrete casting



Figure AN. E-15: Concrete chemical attack



Figure AN. E-16: Water Cured concrete



Figure AN. E-17: Compressive strength test



Figure AN. E-18: Crushed Concrete

Appendix: F

Chemical, Physical and Mechanical Properties of the Cement

MESSEBO CEMENT FACTORY
QUALITY CONTROL LABORATORY
QUALITY CERTIFICATE

REPORT FOR: CUSTOMER

QC/4/012
 Issue-1
 Page: 1 of 1

Product Type Portland Pozzolana Cement

Date of Report 9/9/2009

Date of Dispatch 7/5/2009 to 7/10/2009

Report Type: Weekly Report

Parameter	Test method	Unit	Limit	Date of Testing	Measured	Remark
Sulfur content	EN196-2	%	Max 4.0	/5-10/July/2009	2.46	
Chloride Content	EN196-21	%	Max 0.1	/5-10/July/2009	0.01	
LOI	EN196-2	%	Max 3.0	/5-10/July/2009	1.23	
Comprehensive Strength	2 day	EN196-2	N/mm ²	Min 10.0	/5-10/July/2009	13.8
	28 day	EN196-2	N/mm ²	Min 32.5	/5-10/July/2009	56.6
Setting time	initial	EN196-3	Minute	Min 75	/5-10/July/2009	155
	final	EN196-3	Minute	Max 600	/5-10/July/2009	195
Soundness	EN196-3	mm	Max 10	/5-10/July/2009	1.25	
Specific Surface Area	BS EN196-6	cm ² /g	-	/5-10/July/2009	2970	
Heat of Hydration	3 day*	BS 1370	KJ/kg	-	/5-10/July/2009	153
	28 day	BS 1370	KJ/kg	-	/5-10/July/2009	258
Percentage of Pozzolana*		%	-	/5-10/July/2009	25 %	
Specific gravity		g/cm ³	-	/5-10/July/2009	-	

Chemical Analysis result: SiO₂=29.14 Fe₂O₃=5.91 Al₂O₃=6.76 CaO=55.86 MgO=1.52 SO₃=2.94 LOI=2.31

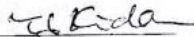

Yohannes G. Kidan
 Quality Control Manager
 Date: 9/9/2009

Figure EN. F-1: Properties of cement