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**SCHOOL OF GRADUATE STUDIES  
ADDIS ABABA UNIVERSITY  
ADDIS ABABA INSTITUTE OF TECHNOLOGY  
SCHOOL OF CIVIL & ENVIRONMENTAL  
ENGINEERING**

**FINE AGGREGATE PRODUCTION AND ITS  
ENVIRONMENTAL IMPACT IN SOME  
SELECTED SITES OF THE RIFT VALLEY  
AREA IN ETHIOPIA**

A thesis submitted to the School of Graduate Studies of Addis Ababa University  
in Partial fulfillment of the requirements for the Degree of Master of Science in  
Civil Engineering (Construction Technology and Management)

By  
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**November 2014  
Addis Ababa**

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## ACRONYMS & ABBREVIATIONS

ASTM	American Society for Testing and Materials
AASHTO	American Association of State Highway and Transportation Officials
EPA	Environmental Protection Authority
EIA	Environmental Impact Assessment
Fig.	Figure
F.M	Fineness Modulus
gm	gram
i.e.	That is
in	Inch
Ltd.	Limited
Max.	Maximum
Min.	Minimum
ml	milliliter
mm	millimeter
m <sup>3</sup>	cubic meter
µm	micro meter

## ABSTRACT

In today's world the use of natural aggregate has increased extensively. We live our lives dependent on an infrastructure created out of concrete. Concrete is a composite material of which 60-75% by volume is aggregates. Out of this volume, 30-40% is constituted by fine aggregates. Although potential sources of fine aggregates are widespread and large, land-use choices, economic considerations, and environmental concerns may limit their availability. Making aggregate resources available for our country's increasing demand will be an ongoing challenge. Understanding how fine aggregates are produced and what environmental impacts they bring about is an important point to investigate. With this in mind, this research has been undertaken to assess the production process of fine aggregates in some sites of the Oromia region in Ethiopia and the environmental impacts concerned with them. It concentrates on both the positive and negative impacts of sand mining. Positive in terms of financial gain and provision of building material; and negative in terms of the environmental impact it brings about.

The production of fine aggregate is not the extraction of the mineral from the source alone but basically involves a number of steps starting from the exploration, mining, processing, transporting and finally reclamation. A visit to three different sites was made along with interviews. From the site visits, it has been found that exploration process has not been undertaken in all of the sites. In all the three sites the mining process used is the artisanal technique which does not employ any machineries but mining is carried out by human labor - making use of hand shovels. In other countries, the sand goes into various combinations of washers, driers, screens, and classifiers to segregate particle sizes, crushers to reduce oversized material, and storage and loading facilities. None of this has been seen in the sites visited. Transportation in all the sites was carried out by making use of a domestic animal - a donkey to an all-weather road and then transported using a dump truck. Even though all the three visited sites are currently active, it has been understood

from interviews that reclamation is not normally done for sites which have been closed down.

The research further showed that the environmental impacts associated with sand mining are impact on the Riparian Habitat, Flora and Fauna, land degradation, loss of aesthetic value, loss of the stability of the structures, the decrease in water as well as the air quality, damage to roads, the use of unplanned access roads damaging the farm lands damaging their crop, diversion of the canal and, siltation in the downstream areas, i.e. the Awash basin. Moreover, samples from the visited sites were taken and tests were conducted for silt content and gradation. The results have displayed that none of the samples have passed for quality requirements set by the standards for silt and gradation. The production capacity of the workers in all the three sites is minimal and sales price at the sites is somewhat fair but extremely high when it comes to sales in kality area.

Moreover, the production of fine aggregates in the rift valley area of Ethiopia is still in the primitive stage. It does not coincide with the standards with respect to production process, quality, and production capacity. The environmental impacts that fine aggregate production bring about are hardly known in this country.

**Key words:** Concrete, Environment, Exploration, Fine aggregate, Impact, Mining, Processing, Production, Reclamation, Transportation, Quality

# 1. INTRODUCTION

---

## 1.1. Background

Human activities throughout the world are resulting in severe damages to the environment. To cite just a few wildfires, flooding, tsunami and drought due to global warming, rising of sea level, depletion of the ozone layer causing increasing threats of cancer and land loss due to contamination of soil are among the damages. The Construction industry is one of the major industries contributing to these environmental threats. It is not uncommon to see so many natural resources being depleted due to extensive use of these resources used in the construction industry.

According to the United Nations Environment Programme, it has been understood that next to water, concrete is the second-most consumed substance on earth; on average, each person uses nearly three tons of concrete a year. Concrete constitutes of cement, aggregate and water. Portland cement, the major component of concrete, is used to bind the materials that make up concrete. The concrete industry uses about 3.6 billion metric tons of Portland cement and produces some 11 billion tons of concrete a year [1].

Almost all commercial activities are undertaken in buildings and on highways, air, rails, and marine systems that require concrete and asphalt-bound structures which is comprised of almost totally aggregate. In volume, aggregate comprises about 65-85% of these structures; the binder (Portland cement in concrete and bitumen in asphalt pavement) and the reinforcing skeletons made of structural steel comprise the remaining percentage.

The construction industry uses significant amounts of natural resources such as limestone and sand, and depending on the variety and process, requires 60-130 kg of fuel oil and 110 kWh of electricity to produce each tons of cement. Producing one ton of Portland cement releases roughly one ton of CO<sub>2</sub> to the atmosphere, and sometimes much more,

and the cement industry accounts for 7-8% of the planet's human-produced CO<sub>2</sub> emissions. Half of it comes from producing clinker, 40% from burning fuel and 10% from electricity use and transportation [2].

The amount of these important construction materials we use each year is very surprising. Annual production of aggregate worldwide totals about 16.5 billion tons (15 billion metric tons). This values more than \$70 billion which in turn makes aggregate production one of the most important mining industries in the world [3].

Our demand for construction aggregate is increasing. Figure 1 shows the historical and estimated future use of construction aggregate in the Unites States until the year 2025. It is projected that in the United States the use of construction aggregate in the next 25 years will be almost as that which has been used up in the entire 20<sup>th</sup> century. Aggregate is needed to repair existing infrastructure, create new infrastructure for the country's growing population, and to meet the demands of changing lifestyles for bigger and better houses and highways. Meeting these needs depends on the availability of large supplies of aggregate [3].

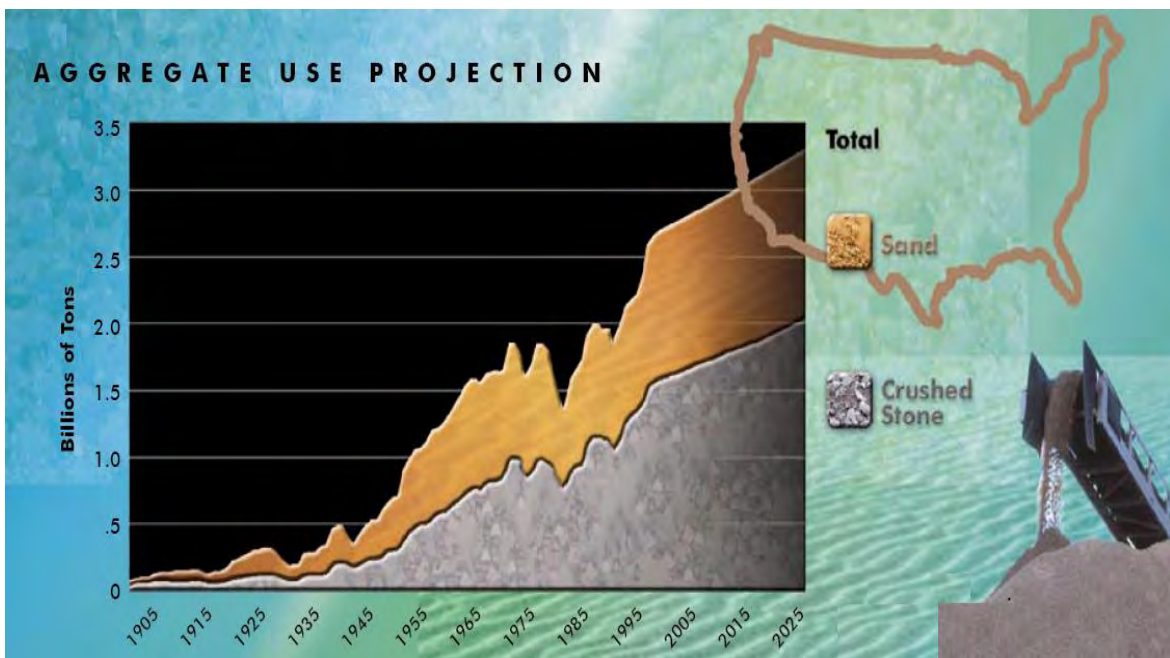


Figure 1 Aggregate use projections in the United States [3].

Even though natural aggregates are widely distributed throughout the world, it is not necessarily available for use. Some areas do not have sand and gravel, and potential sources of crushed stone may occur at depths that make extraction impractical. In other areas, natural aggregates may not meet the quality requirements for use. Furthermore, an area may contain abundant aggregate suitable for the intended purpose, but conflicting land uses, zoning, regulations, or citizen protests may prevent its development and production.

Aggregate production basically turns big rocks into little rocks and carefully sorts them by size. Excavating crushed stone or sand and gravel is dependent on the geologic characteristics and the extent and thickness of the deposit. Open-pit mining and quarrying methods are commonly used, although some stone is mined underground. Quarrying and mining stone generally requires drilling and controlled blasting before the rock is extracted with power shovels, bulldozers, and draglines. Sand and gravel deposits commonly are excavated with conventional earth-moving equipment such as bulldozers, front-end loaders, and tractor scrapers, but may be excavated from streams or water-filled pits with draglines or from barges that use hydraulic or ladder dredges [3].

Once the aggregates are extracted from the quarry site, the next step that takes place is processing. Processing includes crushing, sorting, washing, sizing and transporting. Crushing reduces the size of the aggregate depending on the requirements for the final product. After crushing, the aggregate is sorted to size. Silt and clay are removed by washing. At this stage, aggregate commonly is moved by conveyors to bins or is stockpiled by size. Finally, aggregate is loaded on trucks, rail, barges, or freighters for shipment to the site of use [3].

Transportation to the final destination is not the end to aggregate production reclamation, returning the land to a beneficial use, is the final step of aggregate production. Reclaimed pits or quarries have been converted to many uses including residential developments, botanical gardens, recreational areas, wildlife areas, farmland, industrial and commercial

properties, etc. Reclamation commonly is planned before mining begins, allowing the pit or quarry to be developed in a manner that facilitates final reclamation [3].

Aggregates in general have an enormous use in the construction industry. Despite their use, the mining and processing of these natural resources raises concern about the potential environmental impacts it bring about.

### **What are the Environmental Concerns?**

As shown in figure 1, the demand for both coarse and fine aggregate is increasing extensively. Fine aggregates account for about 30-40% of concrete production. The increase in demand for aggregate in the construction industry has placed an enormous amount of pressure on sand and gravel resources. Sand and gravel mining is a direct and obvious cause of environmental degradation.

Through a natural process of erosion and deposition, sand and gravel deposits are formed in rivers and their floodplains. Rivers, not only comprise of sand and gravel, but are also home to many faunal and floral species. The extraction of sand and gravel from rivers and their floodplains conflict with the functionality of riverine ecosystems. In addition to the impact on the living species, the most common environmental impact is the alteration of land use, effect on both ground and surface water, depletion of the soil quality etc. [4].

Moreover, the actions of human activities bring about effects such as dust, noise, and vibrations. These impacts commonly can be controlled, mitigated, or kept at tolerable levels and restricted to the immediate surroundings of an aggregate operation by using available technology [3].

The demand for aggregate continues to grow with the ongoing living standard of the society. These demands, however, should not be obtained without considering the environmental impacts which might occur. The question is not whether to choose between aggregate and the environment, but rather how balance can be made among the economic, social, and environmental aspects of aggregate resource development.

### **The Ethiopian context**

Mining plays an important economic role in Ethiopia. The resources discovered in different regions of the country are mainly gold, tantalum, phosphorus, iron, salt, potash, soda ash, gemstones, coal, geothermal and natural gas, apart from many industrial and construction materials [5].

One of the significant construction materials is that of sand or fine aggregate, which is mostly naturally obtained by extracting it from rivers and/or river beds. Moreover, finely crushed aggregate is also used in some parts of the country where natural sand is not available [6].

Sand production in Ethiopia is done by making use of Artisanal miners. The method employed does not make use of machineries, but rather only simple equipments like hand shovel. According to Denamo (2005), the production method of sand in Ethiopia is so primitive that the sand produced is prone to a greater degree of non-uniformity and contamination by deleterious substances. Moreover, there is no quality check and standardization of the products. He further stated that due to the primitive production process, there is wastage of materials [6].

According to the Minerals yearbooks of Ethiopia, the production capacity for construction sand in the year 2009 was found to be 840 thousand metric ton. The same amount was recorded for the year 2010 and 2011. No data was found from then onward. Noting that this much mineral has been extracted, it is important that special attention is given to sand production and its process.

## **1.2. Objectives of the study**

### **General Objective**

The general objective of the study was assessment of the current production process of fine aggregate in some selected sites of the rift valley area in Ethiopia and the environmental impact it brings about, followed by discussions and recommendations in accordance with the outcome of the research.

### Specific objectives

Having described the general objective, the specific objectives of the research were to:

- present an overview of the concept of „fine aggregate production and its environmental impact“;
- give the general public, educators, and policy makers a better understanding of the production process followed for fine aggregates and the environmental concerns related to them;
- analyze the fine aggregate samples for compliance with the standard sets;
- assess the production capacity for fine aggregates and the sales price related to it;
- forecast the future prospect for fine aggregate.

### 1.3. Scope and Limitations of the study

Aggregates in concrete comprise of both fine aggregates commonly known as sand and coarse aggregates referred to as gravel. The environmental impacts fine aggregates bring about are the ones that are covered in this thesis as for coarse aggregate a lot of the work has been covered by Semere Mulatu (2012) in his thesis titled *„environmental impacts of coarse aggregate production in and around Addis Ababa“*.

Fine aggregates in general may be those found naturally (pit, river or marine sand) or those which are manufactured (manufactured sand). This thesis only covers the natural type of fine aggregates. Manufactures sand is beyond the scope of the study and has been generally covered by Shewaferaw Dinku (2006) on his thesis titled *„the use of manufactured sand in concrete Production: test results and cost comparison‘*.

Pit sand, river sand and marine sand being the different sources of natural fine aggregate the research generally focuses on the river type of fine aggregates which are used in concrete making. Moreover, the research was done only in one of the woreda“s along the rift valley which is the Lume woreda. The three selected were found 80-85km from the

capital city, Addis Ababa. These sites were selected on the basis of proximity as compared with other sites found in the same woreda or other woredas.

#### **1.4. Organization of the study**

This research contains five chapters as described below:

- Chapter One is an introductory part containing discussions on the background, objectives of the study - general and specific and the organization or layout of the study.
- Chapter Two presents literature review with general descriptions by different researchers on fine aggregates and the environmental aspects related to it.
- Chapter Three describes the methodology employed in order to achieve the objectives stated above.
- Chapter Four gives the results and discussions on fine aggregate production in some selected sites of the rift valley area in Ethiopia and the environmental aspects, impacts and risks that come from the production process.
- Chapter Five gives the conclusion and recommendations in accordance with the results obtained in chapter four.

## 2. LITERATURE REVIEW

---

### 2.1. Environment definition

Environment is everything that makes up our surroundings and affects our ability to live on earth- the air we breathe, the water that covers most of the earth's surface, the plants and animals around us, and much more.

Saleem defined Environment as “the surroundings, external objects, influences, or circumstances under which someone or something exists”. Wikipedia defines it as “the sum total of what is around something or someone. It includes living things and natural forces. The environment of living things provides conditions for development and growth, as well as of danger and damage. Living things do not simply exist in their environment. They constantly interact with it. Organisms change in response to conditions in their environment. The environment consists of the interactions among plants, animals, soil, water, temperature, light, and other living and non-living things” [7].

Therefore, environment is concerned with our way of life. The air we breathe, the water we drink, the food we eat, the things that surround us etc.; it deals with every single aspect of our life to bring about a better living for us.

In recent years, scientists have been carefully examining the ways that people affect the environment. They have found that we are causing air pollution, deforestation, acid rain, and other problems that are dangerous both to the earth and to ourselves. These days, when you hear people talk about “the environment”, they are often referring to the overall condition of our planet, or how healthy it is [8].

## 2.2. Fine aggregate overview

### 2.2.1. General

Aggregate, which is found in nature, consists of grains or fragments of rock. These materials are mined or quarried, and they are used either in their natural state or after crushing, washing, and sizing. Sand, gravel, and crushed stone are commonly combined with binding media to form concrete, mortar, and asphalt. They also provide the base that underlies paved roads, railroad ballast, surfaces on unpaved roads, and filtering material in water treatment [9].

Aggregates consist of about three fourth of the volume of concrete. The property of the aggregate greatly affects the property of the resulting concrete. An ideal aggregate would be one that is inert; but this is not the case for most. The physical, chemical, mechanical and thermal properties of aggregates manipulate the quality of the concrete. The use of aggregate in concrete greatly reduces the needed amount of cement, which is important from both technical and economical standpoints [10].

Aggregates may be broadly classified as natural or artificial, both with respect to source and to method of preparation. Natural sands and gravels are the product of weathering and the action of wind or water, while manufactured crushed fine aggregate and crushed stone coarse and fine aggregate are produced by crushing natural stone. Crushing, screening, and washing may be used to process aggregates from either sand and gravel deposits or stone quarries. Synthetic aggregates may be either by products of an industrial process, in the case of blast-furnace slag, or products of processes developed to manufacture aggregates with special properties, as in the case of expanded clay, shale, or slate used for lightweight aggregates [11].

It has been understood from different literatures that aggregates can further be classified based on different basis. The most commonly used classifications are based on size as coarse and fine; mineralogy and petrography as Igneous, Metamorphic and Sedimentary; chemical composition as Argillaceous, Siliceous and Calcareous; weight as heavy, normal and light; source as natural and artificial; and finally based on particle size and

shape. The last one is the most frequently used classification. Based on this classification, this thesis generally focuses only on the natural type of fine aggregates.

On this basis, one can distinguish between fine aggregates, consisting mostly of small particles, and coarse aggregates, consisting mostly of large particles [10]. Fine aggregates often called sand (BS 882; 1992) are of size not larger than 5mm and that of coarse aggregate is with size at least 5mm.

Sand is the principal component of concrete, the critical construction material and deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers may be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion. Whichever size the producer decides to eliminate for quality reasons, obviously, also affects the sizing [12].

Moreover, sand is a key component of inland and coastal eco-systems. Unselective mining of sand degrades rivers beds, make rivers change course, and degrades the fishery base. Sand helps maintain groundwater tables and keeps saline water from intruding into freshwater sources in coastal areas. Beach sand is our natural defense against rising sea-levels [12].

To have an impression on both the beneficial and adverse effects sand mining brings about Environmental impact assessment (EIA) is mostly undertaken. This is a process of evaluating or predicting the likely environmental impacts of sand production, taking into account interrelated socio-economic, cultural and human-health impacts. The purpose of the assessment is to ensure that decision makers consider the environmental impacts when deciding whether or not to proceed with a project i.e. the production process.

Being an important component for concrete, obtaining good quality natural sand is critical. These easily available natural resources usually accompany gravels which basically imply the deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table

differs in fines content and quality from that found above the water table, due to this subsurface drilling, sampling, and testing are necessary to know to what degree and where these differences occur [12].

As naturally existing material sand may not exist in a pure state i.e. some very fine particles such as dust, silt and clay may intrude in it. In order to remove the necessary amounts of these fines most sands are produced with wash water and water classification. The key to all rinsing and water classifying systems is adequate delivery of water. Inadequate water supply and poor maintenance are the two most common reasons for inconsistent sand gradations [12].

### **2.2.2. Sources of fine aggregates**

Sand is the second most widely used commodity on earth after water. Almost 80 percent of the construction industry is made up of sand. The booming construction industry, real estates, the buildings in which majority of government offices are, etc., all are constructed with the help of sand [13]. So, how is this important mineral formed and where is it found?

Generally, sand is found on the banks of rivers and beaches of seas or oceans. The rivers carry sediments with them and due to erosion in the due course of motion rounding of boulders happens from which small fragments are released from the parent rock and the process continues with the newly formed fragments along with boulders. Thus, minute particles finally suspend and are carried along with the river flow which is generally termed as sand. Whenever we are mining the sand from these areas, there is always a “replenishment capacity per year” associated with every river or bank in a particular area. If sand is mined within this limit, then it is environmentally sustainable- else, disasters are prone to happen [14].

It is generally accepted that sand and gravel are widely distributed and abundant near existing and past rivers and streams, in alluvial basins, and in previously glaciated areas. Regardless of the wide distribution, these aggregates are not universally available for use.

Where the locality lacks the aggregate source, the costly alternatives of importing aggregate from outside the area or substituting another material for aggregate is considered.

Basically, the sources of natural fine aggregate are of three types [15, 16, and 17]:

**2.2.2.1. Pit sand (Coarse sand)**

This type of sand is procured from deep pits of abundant supply. It has a property of being coarse grained which is sharp, angular and free from salts. It mostly has a reddish yellow color and mostly employed in concreting [15, 16, and 17].

**2.2.2.2. River sand**

The River sands are obtained, as the name implies, from banks or beds of rivers. River sand has the property of being fine and consists of fine rounded grains. The color of river sand is almost white and grayish. River sand is usually available in clean condition and is used for plastering [17].

**2.2.2.3. Sea/Marine sand**

As the name implies, sea sand is taken from sea shores. It has fine rounded grains and it is light brown in color. Sea sand is avoided for the purpose of constructing concrete structure since it contains salt and tends to absorb moisture from the atmosphere and brings dampness [16, 17].

**2.2.3. Fine aggregate/sand production**

Sand is one of the most accessible natural resource that has been used since the earliest days of civilization mostly as a construction material.

According to USGS, the largest producer of sand and gravel in the world is the United States, produced 26.5 million metric tonnes of the materials. Italy ranks second with an annual production of over 14 million metric tonnes. The third place is occupied by Germany, producing 6.5 million metric tonnes [18].

Other major countries producing sand and gravel include the United Kingdom, Australia, France, Spain, Poland, Japan, Mexico, South Africa, Finland, Belgium, Egypt, India, Iran, Norway, Austria, Chile, Czech Republic, Turkey, Canada, Gambia, Bulgaria, Slovakia, South Korea, and Hungary [18].

A summary of the top fifteen producers of sand and gravel along with their production capacity is shown in table 1.

Table 1 Top 15 producers of sand and gravel in the world [18].

<b>Rank</b>	<b>Country</b>	<b>Production in Thousand Metric Tonnes</b>
1	United States	26,500
2	Italy	14,000
3	Germany	6,500
4	United Kingdom	5,600
5	Australia	5,200
6	France	5,000
7	Spain	5,000
8	Poland	4,350
9	Japan	3,500
10	Mexico	2,800
11	South Africa	2,300
12	Finland	2,240
13	Belgium	1,800
14	Egypt	1,750
15	India	1,700

The production of fine aggregate starts with the exploration process where locating a suitable resource near the area is done. Once the exploration is done, it is followed by the mining process where the actual extraction of the material takes place. To enhance the quality of the extracted fine aggregate, it is further processed through washing, drying, sorting, and storing. This is followed by transportation to the final destination. Delivering to the final destination is not an end to the production process. A reclamation program is required where maintenance to the interrupted land takes place. A detailed description of each step is discussed below.

### **2.2.3.1. Exploration**

A mining project begins once knowhow on the extent and value of the mineral ore deposit has been accomplished. Information on the location and value of the mineral ore deposit is obtained during the exploration phase. This phase includes surveys, field studies, and drilling test boreholes and other exploratory excavations [19].

The exploratory phase may involve clearing of wide areas of vegetation, to allow the entry of heavy vehicles mounted with drilling rigs. Many countries require a separate EIA for the exploratory phase of a mining project because the impacts of this phase can be intense and further phases of mining may not follow if exploration fails to find sufficient quantities of mineral ore deposits.

### **2.2.3.2. Mining**

Mining is the actual removal of the material from the source. Before any actual mining is done at a site, overburden which is mainly composed of silt, loam, clay, or combinations of the three is removed from the top of the sand formation with the help of scrapers or tracked excavators and off-road haul trucks.

Once the overburden has been removed, the sand is mined out either by open pit excavation or by dredging. Open pit excavation is carried out with power shovels, draglines, front end loaders, and bucket wheel excavators. Depending upon the geological formation, blasting may be used to loosen the sand deposit followed by the crushing process to reduce the size. Mining by dredging involves mounting the equipment on boats or barges and removing the fine aggregate and gravel from the bottom of the water body by suction or bucket-type dredges [20, 21].

Having obtained the mined mineral, the material may be directly used without further processing, taken directly to the washing process, stockpiled on site for later processing, or transported to a processing plant [21].

Although significant amounts of sand and gravel are used without processing, most sand and gravel are processed prior to use. Therefore, the materials are transported to the processing plant by suction pump, earth mover, barge, truck, belt conveyors, or other means [20].

### **2.2.3.3. Processing**

Sand must be of uniform size and shape. To achieve this uniformity, the sand is run through a processing plant. The processing of sand and gravel involves the use of different combinations of washers, driers, screens, and classifiers to segregate particle sizes; crushers to reduce oversized material; and storage and loading facilities [20]. A picture representation of a typical drying machine used to dry the sand, a sand dewatering tower and grading machine are shown in figure 2.

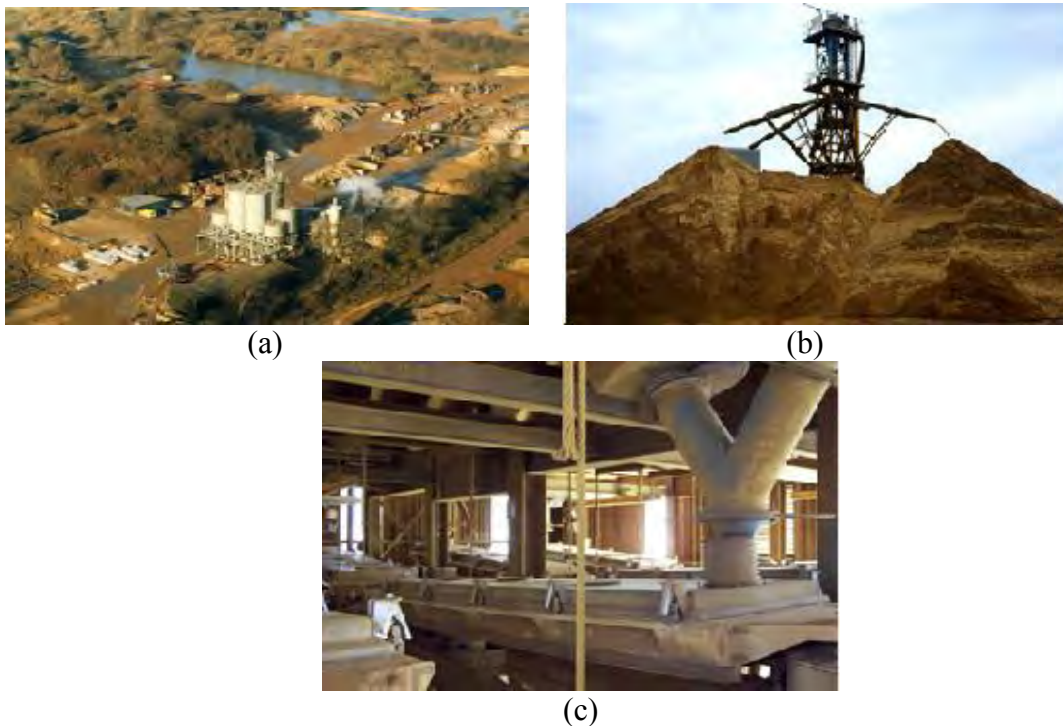


Figure 2 (a) A typical drying plant; (b) Sand dewatering tower; and (c) Grading machine [22].

### **Washing**

The purpose of washing sand is to free it from fine particles, clay and organic impurities. Washing is done by spraying the sand with water as it is carried over a vibrating screen. The fine particles are washed off the sand and the coarse particles are carried along the screen by the vibration. Some processing operations also use what is known as an upflow clarifier to wash the sand. An upflow clarifier is essentially a tank where water and sand are continuously directed into the tank. The water washes the sand and the overflow water along with the fines flow over the tank while the washed sand falls by gravity to the bottom of the tank and is sent for further processing [21].

Modern quarries use attrition scrubbers which remove silt and gravel from the sand particles using the abrasive power of water and hydro-cyclone systems, which in turn use pressurized water jets to float the fine grains of sand away from the coarse grains. Solid particles that are separated from the finer sand particles are allowed to settle in silt lagoons [22].

### **Drying**

Prior to sand being sized and stored as a final product, it typically goes through a drying process to reduce the moisture content. Once the sand has been washed, it is then sent to a surge pile where much of the water adhering to the sand particles infiltrates back into the ground. From the surge pile, the sand is sent to the dryer and screening operation. As shown in figure 3 the sand may be dried by feeding it into a large rotating drum with a hot air blast or making use of fluidized bed dryer [21].



(a)



(b)

Figure 3 Sand drying alternatives; (a) rotating drum; (b) fluidized bed dryer [21].

Once the sand is dried, it is cooled and may be further sorted by screening. The dried sand is then fed by conveyors to storage bins or directly to a screen house via conveyors [21].

### Sorting and Screening

After the sand passes through the drying phase, it is graded to produce the grain size needed for a particular purpose. Vibrating screens are used to screen the sand; these can be changed to produce the different grain sizes [22].

The screens separate the oversize material from the smaller, marketable sizes. Oversize material may be used for erosion control, reclamation, or other uses, or it may be directed to a crusher for size reduction, to produce crushed aggregate, or to produce manufactured sands. Following crushing, the material is returned to the screening operation for sizing [20].

In modern processing plants, different grain sizes can be selected. The graded sand is then conveyed to storage silos or on to a bagging shed. The whole operation is controlled from a central diagnostic desk, controlling flow and storage. The sand is tested several times at various stages of the process to ensure that it conforms to the specifications of that particular grade of sand [22].

Once washed, dried, graded and tested; the sand is stored in piles or bagged ready for transportation. In the case of the bagged sands, the correct weight of sand is deposited into each polythene sack, which is sealed and sprayed with a batch number, date and grade and moved to the waiting lorries [22].

#### **2.2.3.4. Transporting**

Transportation of sand from the time it is mined, processed, and eventually delivered to the location where it is going to be used can take many mediums depending upon the location of the mine, the processing facility and the destination where the sand will ultimately be used. Transportation is a key element of the supply process and a large part of the delivered price. Within the mine, the sand may be transported by front-end loaders, large open-topped off-road trucks, or dump trucks [21].

Vehicular traffic on local roads will have an impact on the service life and condition of the roads. The degree of road deterioration will depend on the amount of traffic, the type of vehicles, and the design of the road. Rail (figure 2 (b)) currently seems to be the preferred method of transporting sand from the mine or from the processing plant to the location of final use [21].

Similarly, aggregates can be transported using the network of inland waterways (figure 2 (c)). Although this is a much less common form of transportation, it can provide a very useful means of connecting isolated deposits to established processing plants [23].

Non-road methods of transporting supplies of aggregate are therefore very important. However, due to the flexibility of road transportation (and the relative inflexibility of rail and water transportation), the product is often ultimately delivered to its final point of sale by truck (figure 2 (a)) [23].

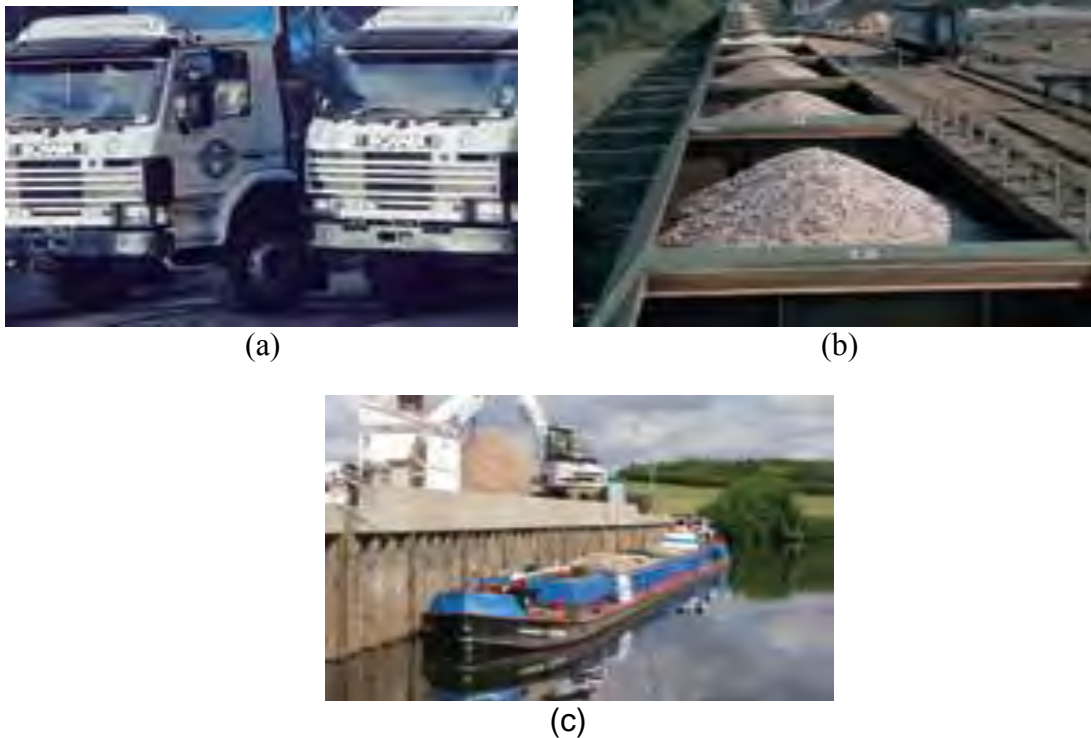


Figure 4 Sand Transportation alternatives; (a) Truck; (b) Rail; and (c) waterways [23].

#### 2.2.3.5. Reclamation

When active mining ceases, mine facilities and the site are reclaimed and closed. The goal of mine site reclamation and closure should always be to return the site to a condition that most resembles the pre-mining condition. Therefore, the EIA for every proposed mining project must include a detailed discussion of the mine Reclamation and Closure Plan offered by the mining body [19].

Mine reclamation is the process of restoring land that has been mined to a natural or economically usable state. Although the process of mine reclamation occurs once mining is completed; the preparation and planning of mine reclamation activities occur prior to a mine being permitted or started. Mine reclamation creates useful landscapes that meet a variety of goals ranging from the restoration of productive ecosystems to the creation of industrial and municipal resources. Modern mine reclamation minimizes and mitigates the environmental effects of mining. [24]

The goal of reclamation is to return the land to a beneficial use. By planning reclamation before the aggregate is extracted, it can be mined with how the quarry will look when it is reclaimed. This can make it easier to turn quarries into scenic, lake-front property, wildlife parks, golf courses, office parks and the many other items a quarry can eventually become. Parts of the mine can be reclaimed while continuing on-going mining operations in some instances [25].

Throughout the world, to overcome the problems associated with mining, attempt is being made to reclaim mining sites to a beneficial use. For instance, in the United States, where mining is the core in the country, different reclamation programs have been applicable. An exemplar showing a reclaimed mining site in the United States is shown in figure 5.

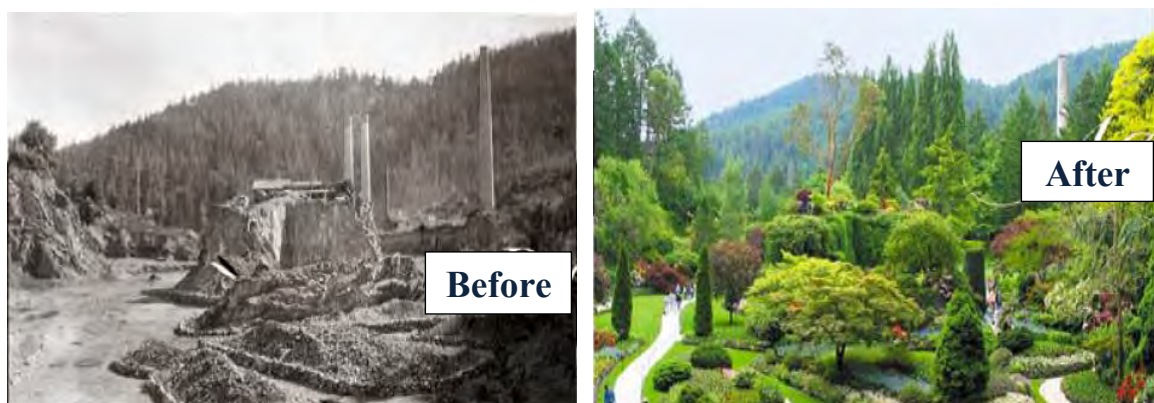


Figure 5 Reclaimed mining site in the United States [3].

In South Africa, which is the number one sand and gravel producer in Africa, the applicant when applying for mining site permit must lodge a financial provision for the purposes of rehabilitation of the site once mining is completed. Moreover, there are additional obligations on an applicant to submit an environmental management programme or environmental management plan. It is once the license provider proves that the applicant has made financial provision for the rehabilitation or management of negative environmental aspects; and when it is proved that the applicant has the capacity to rehabilitate and manage negative impacts on the environment that permit is given [26].

## 2.2.4. The Ethiopian context

### 2.2.4.1. Fine Aggregate production

The production of fine aggregate in Ethiopia is mainly by the process of extracting from river beds. Crushed aggregates are also being used in some parts of the country to serve as sand when there is a scarcity or unavailability of natural sand.

Due to over flow of rivers and inaccessibility to the site, natural sand obtained from river sands are difficult to produce during the wet season [6].

Denamo stated that the sand production sites found in Ethiopia are not mechanized but rather make use of the traditional method where the local people of the area are the producers and transportation is done by donkeys that have a maximum carrying capacity of 70kg or 0.05m<sup>3</sup> per trip. The donkeys transport it to a place where vehicles have access. Sand is then loaded to vehicles manually and transported to the actual site or to construction material suppliers which is then directly used for the intended purpose [6].

Fine aggregates (sand), is unconsolidated and highly variable mixtures of different constituents. The construction industry utilizes sand mainly from streambeds, which are commonly derived from quartzo-feldspathic basement rocks, sandy marine sediments and alluvial deposits. The major sand supply for the construction works in and around Addis Ababa is the Awash basin located about 70-120 km southeast of the city. The method of quarrying sand is generally very old and the producers do not attempt to clean and grade the sand right from the source. A sand with a silt content as high as 20% is usually purchased from those quarry sites. Typical method of sand quarrying operations and transporting to the nearby loading station using animal transport are shown in figure 6 [27].



Figure 6 Typical sand quarrying practices along the Awash basin and Transporting of quarried sand to loading trucks [6].

It has been learnt that the fine aggregate production process in Ethiopia is so old fashioned that it is prone to non-uniformity in gradation, susceptible to contamination by deleterious substances; there is no room for quality check, there is no standardization, there is no consistent supply from a specific area [6].

#### **2.2.4.2. Demand vs. supply**

In Addis Ababa, various construction activities are ongoing. In relation to the expansion of these construction activities, the demand for construction materials including gravel and sand is growing rapidly. The demand for construction aggregate is directly related to the volume of the construction works [6].

Construction aggregate prices are expected to increase in the future due to the rising cost of fuel used in the production and transportation processes. The rise in fuel cost is expected to affect the delivery prices of construction sand and gravel. These price increases are expected to be more noticeable in and near cities because as nearby resources are used up, more aggregates will have to be transported from distant resources [28].

Do we have enough fine aggregate currently? This is a question that occurs in most people's head. Even though there is no first hand data on how much sand is needed to

fulfill the demand, attempt has been made by the researcher to find an approximate estimate based on the current quantity of cement produced. According to Addis Fortune newspaper (May 4, 2014), the production capacity of the cement factories in Ethiopia if they produce with full capacity is 9 million tons, but the companies are not producing with full capacity currently. Therefore assuming the supply of cement to be 6 million tons and out of this, if 80% of it is used up for concrete, then 4.8 million tons is used by concrete. 30-40% of concrete being sand, the demand for sand would be approximately 1.5 million tons per year. This is equivalent to what India is producing, the fifteenth largest sand and gravel producer in the world. However, Ethiopia is not even in the top fifteen countries" list.

From the interview made with Addis Ababa housing construction project office staff, it has been found that there is shortage in the supply of aggregates for the 40,000 houses planned to be accomplished. Therefore, one can conclude that the demand is not being met.

### **2.2.5. Quality requirement of fine aggregate**

The quality of fine aggregate used in concrete has a bearing effect on the quality of the final output. Therefore, standards have been set in order to help obtain the desired concrete quality. Some of the requirements are discussed below:

#### **2.2.5.1. Silt Content**

Sand which is a product of natural or artificial disintegration of rocks and minerals is obtained from glacial, river, lake, marine, residual and wind-blown deposits. These deposits however do not only provide sand but also contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand used to make concrete or mortar decreases the bond between the materials to be bound together and hence the strength of the mixture. The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore it is necessary that one make a test on the silt content and checks against permissible limits.

A simple test which can be made on site to give a guide to the amount of silt in natural sand is the „field settling“ test. This test is based on the fact that large heavy particle will settle rapidly in water while small light particle will settle most slowly. This test is only fit for normal sand and should not be used for crushed rock sands.

The British and American standards (BS 882, ASTM C-33) limit the clay and silt content not to be more than 3% of the total weight of the fine aggregate. Unlike these standard limits the Ethiopian standard gives more allowance by about 3% more. According to the Ethiopian standard it is recommended to wash the sand or reject it if the silt content exceeds a value of 6 % [29].

#### **2.2.5.2. Sieve Analysis**

The most desirable fine aggregate grading depends on the type of work, the richness of the mixture, and the maximum size of coarse aggregate. In leaner mixes or when small-size coarse aggregate are used, a grading that approaches the maximum recommended percentage passing each sieve is desirable for workability. In general, if the water-cement ratio is kept constant and the ratio of fine-to-coarse aggregate is chosen correctly, a wide range in grading can be used without measurable effect on strength. However, the best economy will sometimes be achieved by adjusting the concrete mixture to suit the gradation of the local aggregates [30].

The ASTM C 33 (AASHTO M 6) limits with respect to sieve size are shown in Table 2. The Ethiopia standard (ES C.D3. 201) basically follows the same permit as that of AASHTO M 6 [30].

Table 2 Fine aggregate grading limits (ASTM C 33/ AASHTO M 6) [30].

<b>Sieve size</b>	<b>Percentage passing</b>
9.50mm (3/8 in.)	100
4.75mm (No. 4)	95 – 100
2.36mm (No. 8)	80 – 100
1.18mm (No. 16)	50 – 85
600mm (No. 30)	25 – 60
300µm (No. 50)	5 – 30 (AASHTO 10 – 30)
150µm (No. 100)	0 – 10 (AASHTO 2 – 10)

The AASHTO specifications permit the minimum percentages (by mass) of material passing the 300µm (No.50) and 150µm (No. 100) sieves to be reduced to 5% and 0% respectively, provided [30]:

1. The aggregate is used in air-entrained concrete containing more than 237 kilograms of cement per cubic meter (400 lb of cement per cubic yard) and having an air content of more than 3%.
2. The aggregate is used in concrete containing more than 297 kilograms of cement per cubic meter when the concrete is not air-entrained.
3. An approved supplementary cementitious material is used to supply the deficiency in material passing these two sieves.

Other requirements of ASTM C 33 (AASHTO M 6) are:

1. The fine aggregate must not have more than 45% retained between any two consecutive standard sieves.
2. The fineness modulus must be not less than 2.3 nor more than 3.1, nor vary more than 0.2 from the typical value of the aggregate source. If this value is exceeded, the fine aggregate should be rejected unless suitable adjustments are made in proportions of fine and coarse aggregate.

The amounts of fine aggregate passing the 300 $\mu$ m (No. 50) and 150 $\mu$ m (No. 100) sieves affect workability, surface texture, air content, and bleeding of concrete. Most specifications allow 5% to 30% to pass the 300 $\mu$ m (No. 50) sieve. The lower limit may be sufficient for easy placing conditions or where concrete is mechanically finished, such as in pavements. However, for hand-finished concrete floors, or where a smooth surface texture is desired, fine aggregate with at least 15% passing the 300 $\mu$ m (No. 50) sieve and 3% or more passing the 150 $\mu$ m (No. 100) sieve should be used.

### **2.2.6. Uses of fine aggregates**

Sand has been used widely in the construction industry for many hundreds of years. Even during Roman times, sand was a useful resource, used in the production of tiles. The 1930s saw Leighton Buzzard sand mixed with lime to make special steamed bricks at Stonehenge Bricks Ltd. White, silica-rich, sand from Heath and Reach has also been distributed internationally to major cement manufacturers [31].

More than 200 diverse uses of sand are listed today; including in the leisure and sports industry for golf courses, football pitches and greyhound tracks. Sand is widely used in construction and make up 30-40% of concrete.

Aggregates (Fine and Coarse) are component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and trench drains, septic drain fields, retaining wall drains, and road side edge drains.

Aggregates are also used as base material under foundations, roads, and railroads. To put it in other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete.

Aggregates have three basic functions [6]:

1. To provide a relatively cheap filler for the cementing material;
2. To provide a mass of particles that are suitable for resisting the action of applied loads, abrasion, the percolation of moisture, and the action of weather; and
3. To reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste.

## **2.3. The Environmental aspect: impacts and risks**

### **2.3.1. General**

For thousands of years, sand has been used in the construction sector. Today, demand for sand continues to increase and this has brought about an environmental concern throughout the world.

The mining operations create a variety of impacts on the environment before, during and after mining operations. The extent and nature of these impacts depend on different factors such as the characteristic of the mineral body, the type of technology and extraction methods used in mining and the on-site processing of activities, and the sensitivity of the local environment [33]. A detailed description of the major impact sand mining operations brings about on the environment throughout the world is discussed in section 2.3.2.

It has been reported in different literatures that one of the inseparable impacts caused by sand mining is the degradation of rivers. This lowers the stream bottoms and consequently may lead to bank erosion. Moreover, the loss of sand and gravel from the rivers causes deepening of rivers and the enlargement of river mouths [32, 33, and 34].

Sand mining also affects the groundwater system and the uses that local people make of the river. Sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. In addition, sand mining generates extra

vehicle traffic, which negatively affects the environment. Where access roads cross riparian areas, the local environment may be affected [32].

The effect of mining is compounded by the effect of sea level rise. Any volume of sand extracted from the rivers is a loss to the system. Moreover, excessive sand mining is a threat to bridges, river banks and nearby structures. Therefore, a careful consideration of the river's production level is necessary before mining because a slight failure may lead to huge environmental impact.

### **2.3.2. The impact of fine aggregate production on the environment**

#### **2.3.2.1. Biological/ Ecological Impacts**

It has been reported that during the mining process, removal of channel substrate, re-suspension of streambed sediment, clearance of vegetation and stockpiling on the streambed are commonly observed. These will have ecological impacts which may have an effect on the direct loss of stream reserve habitat, disturbances of species attached to streambed deposits, reduced light penetration, reduced primary production, and reduced feeding opportunities [32].

#### ***Riparian Habitat, Flora and Fauna***

One obvious effect of aggregate extraction is the loss of riparian habitats and species. Not only is there a direct loss of abundance, species diversity and biomass of the benthic community in the mine area, but the effects of turbidity and resettlement of suspended material which comes from the extraction process may cause similar effects over a wider area [34].

It has been reported that due to fine aggregate extraction, many hectares of fertile streamside land are lost annually, as well as valuable timber resources and wildlife habitats in the riparian areas. Degraded stream habitats result in loss of fisheries productivity, biodiversity, and recreational potential. Severely degraded channels may lower land and aesthetic values [32].

Michael et al stated that different researchers have found that due to mining significant effects on fish habitat and abundance have occurred. However, Nelson reported no major differences in fish species and relative abundance from his research in Tennessee. [35].

### **2.3.2.2. Geological/physical Impact**

As mentioned above, aggregate extraction has a physical impact on the aquatic environment. The sediment topography and type will change through the removal of material and resettlement of fine particles. If the human-induced physical disturbances continue, this could lead to continuous erosion and poverty [36].

#### *Stability of Structures*

Various researchers have pointed out that fine aggregate extraction that causes turbulence of basin movements and removal is the main cause of unstable banks. Moreover, it is generally accepted that increased sedimentation, turbidity, higher stream temperature, reduced dissolved oxygen, lowered water table, and decreased rainy seasons are some of the effects directly related to the extraction process [32, 36, and 37].

The changes brought about by the loss of bank stability are the causes for [32]:

- a. the undercutting and collapse of river banks,
- b. the loss of adjacent land and/or structures,
- c. upstream erosion as a result of an increase in channel slope and changes in flow velocity, and
- d. downstream erosion due to increased carrying capacity of the stream, downstream changes in patterns of deposition, and changes in channel bed and habitat type.

#### *Groundwater*

One of the advantages of sand layers along riparian areas is the fact that it serves as a spongy layer and assists in recharge of groundwater through percolation of water through different layers of sand. When these spongy layers are extracted for other purposes such as construction the recharge of groundwater is affected [39].

Moreover, sand mining transforms riverbeds into large and deep pits. This results in the drop of the groundwater table leaving drinking water wells on embankments of rivers dry [32].

#### *Water Quality*

Due to re-suspension of sediments, sedimentation due to stockpiling and dumping of excess mining materials and organic particulate matter, and oil spills or leakage from excavation machinery and transportation vehicles - increased turbidity in sand mining sites are common. These in turn affect the water quality of the river both at the mining site and in the downstream. Suspended solids can significantly increase water treatment costs [39].

#### *Air quality*

The main air quality issue associated with mining is that of dust particles. Large amounts in concentrations of dust can be a health hazard, aggravating respiratory disorders such as asthma and irritating the lungs and bronchial passages. Moreover, people invariably feel a loss of environmental comfort, due to dust deposits or dust concentration [31].

Dust may be the most obvious concern because of its visibility both in the air or when it settles. Known as “fugitive dust,” it fits into a category between 2.5 and 10 microns in size. Fugitive dust from an aggregate operation is the result of wind blowing over stockpiles and exposed soil; blasting, crushing, or sizing of materials; moving of materials on conveyers and trucks; falling material being loaded into trucks or stockpiles; and ground abrasion where truck wheels kick up dust [40].

#### *Land use*

Surface mining results in the destruction of the existing vegetation and soil profile. Removal of overburden and waste rock and its replacement in waste dumps or the mined-out pit can significantly change the topography and stability of the landscape [39].

### *Soil quality*

Due to surface mining of fine aggregate the removal of top soil becomes a necessity. In fact, topsoil is one of the most scarce resources on earth. The topsoil is very seriously damaged if it is not mined out separately in the beginning, with a view to replacement for due reclamation of the area [39].

### **2.3.2.3. Socio-economic Impact**

Socio-economic impacts are impacts that are created on the economic level of a country.

#### **Economic impacts:**

As one of the biggest mineral deposit on earth, sand mining has an economical benefit despite the environmental impact it brings about. For instance, in the United States, as reported by IBIS, revenue of \$11 billion was generated in the year 2013 [41].

In the United Kingdom, the direct turnover of the sand and gravel mining industry has been recorder to be 2,480 million pounds for the year 2005 [42]. In Belgium, a total turnover of 265 million Euros was gained for the year 2002 [36].

#### **Social impacts:**

The social impacts of sand mining are complex and cannot be considered separately from environmental issues. The social impacts coming from river sand mining activities can have both positive and negative effects. The job creation opportunity is viewed as a positive impact. On the other hand, the environmental impacts caused such as pollution, water quality, erosion, etc. affect the society negatively. Therefore, when we look into the socio-environmental components, the negative impacts outweigh.

To cite some examples of the social impacts, employment level of some countries in the United States, the sand and gravel mining industry created 29,012 employment opportunities in the year 2013 [41].

In the United Kingdom, 30,000 jobs have been supported in sand and gravel mining sites in the year 2005 [42]. The total employment in Belgium in the year 2002 has been estimated at about 295 employees [36].

**2.3.2.4. Other impacts of sand mining include [14]:**

- a) Damage to roads: Due to heavy traffic resulting in increased sand transportation by sand loading trucks, roads result in frequent damage and repairs, thus affecting the road traffic, sometimes even prone to accidents.
- b) Scarcity of agricultural laborers: Demand for agricultural laborers increases as most of the laborers engage in sand mining due to the higher wage.
- c) Noise: Due to equipment or machinery used to remove overburden, or process, transport, and load the products; there is an increased noise in mining areas.
- d) Increased use of unplanned access roads lead to soil compaction and vegetation damage along the riparian areas, in addition, causing damage to roads from increased number of sand transporting vehicles.

## **2.4. Mitigation mechanisms**

Modern technology and scientific investigation methods have made it possible to reduce the environmental impacts from aggregate mining and to manage those impacts at acceptable levels. In addition, a variety of federal, state, and local regulations, especially in the developed world as well as some African countries such as South Africa and Gambia, are being designed to limit environmental impacts of aggregate extraction activities.

### **2.4.1. Mitigating physically altered landscapes and habitats**

Properly designed and operated, aggregate operations can minimize the impact to surrounding landscape, nature and the environment. It has been reported by IAAP that through thoughtful site planning and careful design, physical impact of the mining activity can be controlled. The visual impact at the same time can be minimized through sequential reclamation of surface mined areas and construction of buffers/berms or natural screening of ongoing mining operations with trees and shrubs [40].

One of the devastating effects of mining is that of habitat loss. This can be regulated and controlled to some extent, by taking site inventories before extraction begins to identify rare or endangered species. Making use of buffers, relocating animals and plants, creating

a habitat outside the quarry, and sequential reclamation are the major attempts that can be made to overcome the impact [3].

#### **2.4.2. Mitigating pollution to water resources**

As stated in section 2.3.2, sand mining has potential impacts to water resources. It is important to incorporate different techniques to overcome these impacts.

##### **Surface Water**

Removing sand and gravel can cause an increased stream gradient at the site of excavation and a decrease in bed load, which might cause stream erosion in an upstream or downstream direction. Stream erosion can, in turn, cause bank failure and the undercutting of structures. In-stream mining can also result in changes in the sediment load, lowering of alluvial water tables, and stagnant low flows. All of these impacts can result in major changes to aquatic and riparian habitat.

One method of preventing or minimizing impacts from in-stream mining is to define a minimum elevation for the deepest part of the channel along the river and to restrict mining to the area above this line. Another method is to estimate the annual bed load of a stream and restrict extraction to that value or some percentage of it. A third method is to gain an understanding of the behavior and dynamics of a stream and to design extraction techniques with those dynamics in mind [33].

##### **Groundwater**

Any opening in the Earth can act as a conduit for the entry of contaminants. A pit or quarry may act as such a conduit if the potential impacts are not properly controlled. Therefore, limiting the amount or type of chemicals on hand, storing all chemicals and petroleum products in impervious containment areas; careful operating, safety, and training procedures; and controlling surface runoff can be used to avoid the impacts [3].

Moreover, it has been reported that the establishment of observation wells to control the impact of water table from dewatering is one mitigating mechanism.

### **2.4.3. Mitigating dust and noise**

Dust and noise are the two most common impacts of aggregate mining industry. These impacts can however be minimized to a large extent.

#### **Dust**

IAAP stated that in order to control dust produced from processing; the handling equipment may be fitted with water spray equipment or enclosures that minimize dust. Dust generated by haul trucks can be minimized by properly distributing loads; requiring them to be covered by tarps; paving roads leading out and into the facility; installing wheel wash systems; and spraying water on road surfaces [40].

The two most common strategies to overcome generated dust in sand mining sites is making use of either dry dust collection or wet suppression systems. Dry dust collection systems include the use of enclosures and covers on conveyors, screens, and crushers and the use of vacuum systems and bag houses, which remove dust before the air stream is released to the atmosphere. Wet dust suppression systems consist of pressurized water sprays located at dust generating sites, such as conveyors, crushers, and screens. Suppression systems can also be used to wet loads before vehicles leave the plant [3].

#### **Noise**

The primary sources of noise from aggregate extraction are blasting operation, earth-moving equipment, processing equipment, and truck traffic. The best way to manage noise is making use of a good planning technique. Properly designing the site in such a way that it is possible to confine noise on site is important. Some of the ways to achieve this is proper site design which places buildings, stockpiles, earthen berms, and trees or bushes to act as sound buffers. Enclosing processing plants in buildings or shields and fitting the equipment with mufflers and noise reducing enclosures can also be incorporated [40].

Moreover, properly locating access roads, the use of acceleration and deceleration lanes, and careful routing of trucks can help reduce truck noise. Noisy operations can further be scheduled or limited to certain times of the day [3].

#### **2.4.4. Reclamation**

It is obvious that there will be a change in the habitat of any mining site. Restoring the changed habitat into its original condition is seldom possible. The best strategy is to approximate the new habitat as closely as possible to its original function and landscape character. Mined-out aggregate pits and quarries can be converted into second uses that include home sites, wildlife refuges, golf courses, watercourses, botanical gardens, wetlands etc.

The natural reclamation process of abandoned or mined-out quarries can be accelerated through a process called landform replication. Whereby, the reclamation process blends both natural and human efforts. Therefore, by doing this we are putting effort to restore the damage we have brought upon nature [3].

#### **2.4.5. Recycling**

Much of the infrastructure worldwide, particularly older roads, bridges and buildings, are in need of repair or replacement. Demolishing roads and buildings generates large quantities of wastes of asphalt and concrete, and much of these materials can be recycled. Today in the United States, used asphalt pavement and concrete yield more than 200 million tons (180 metric tons) per year of recycled aggregate. Recycling saves huge amounts of space in landfills and allows natural aggregate to be used in applications that require higher quality [3].

By making use of these recycled materials, we are being thoughtful to our non-renewable aggregate resource.

### 3. RESEARCH METHODOLOGY

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In order to assess the production process as well as the environmental impacts of fine aggregate production in some selected sites of Ethiopia, the methodology employed were:

- Literature review:  
This assists in having a clear understanding of the subject matter as well as in identifying what problems exist in the study area.
- Data collection from relevant mines bureau along with interviews.  
From this, specific information with regards to the country as a whole and the study area in particular were obtained.
- Survey at selected active mining sites near Addis Ababa.  
The survey included observation, on-site data collection, sample taking and conducting interviews.  
Actual visit to the site enabled to identify the specific methods employed for sand extraction as well as the environmental concerns associated to it. Moreover, interviews led to better understanding of the trend and the sales price for the mineral.
- Laboratory tests were conducted for the fine aggregate samples gathered on site.  
The compliance of the samples from the sites with the standards was able to be checked and conclusions regarding quality were drawn.
- Use of internet to find relevant information from various websites  
With this, a better understanding was able to be obtained.

Documenting the production process and the environmental impacts produced by fine aggregates in the study area has been difficult because of several complicated factors:

- Lack of regulatory data collection for most mines;
- Lack of “baseline” data that would allow comparisons of pre-mining and active mining conditions.

Due to this, it was only possible to perform qualitative analysis of the production process and the environmental impacts brought by fine aggregates mining for relatively small study areas.

In general, the research was carried out by analyzing the data and information gathered through on site observation, laboratory tests and interviews both on sand mining sites as well as Federal Mines and Energy Bureau.

Three sites which are found 80-85 km from Addis Ababa have been visited from the Oromia region of the country where the majority of sand is imported to the capital city where construction is booming. The sites were selected on the basis of proximity. In the region, the sites were located in the Lume woreda of the East Shoa zone. Samples of three each from the three visited sites were taken and laboratory investigations on silt content and gradation conducted.

The information gathered through interviews, site observations and laboratory test results are briefly discussed in the next section. The practices of Fine Aggregate production as well as the know-how of the environmental impact it brings about were evaluated against the recommended scientific practices.

Finally, test results were analyzed and the level of the fine aggregate quality was assessed from the observed variability in the test results. The compliance of the collected test results with the requirement of various codes and standards was also evaluated. The checklist and the collected test results are attached in the annex part of this thesis.

## 4. RESULTS AND DISCUSSIONS

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For a country like Ethiopia to reach a developed economic state, the development of the domestic construction industry is very important. This is the case since the adequate construction capacity helps to implement other strategic plans, and the industry contributes directly to large-scale employment. The main transformation plan included for our country in the construction sector includes rehabilitation of the existing infrastructures and construction of new civil engineering works, highways, bridges, railway tracks, airports, power plants, water works, and real estate (both residential as well as commercial). In order to accomplish this, huge amount of sand is required, however, does everyone know how these sands are actually extracted/mined, what environmental impact they bring about, what about in regards to quality requirement? Hereunder, these points are thoroughly discussed, accompanied by picture illustrations where required.

### 4.1. Licensing

In Ethiopia as a whole, the attainment of a license for any mining activity is a requirement. There are three levels for licensing:

1. Large-scale with a mining capacity of greater than 80,000 m<sup>3</sup>. This is administered by the region level.
2. Small-scale with a mining capacity of less than 80,000 m<sup>3</sup>. This is administered by the zone level.
3. Artisanal, whereby the mining takes place in a primitive way where there is no use of large machineries. The extraction is basically done by human labor. This is administered by the woreda level. Sand extraction is classified under this mode of licensing. And the license is issued only for a year so that people can change their lives within the one year and pass it over to other jobless people. From this, one can imagine the amount of money one can get in just a year.

During an interview with an official, a question was raised on why machineries were not allowed in the mining process and the response was “because sand extraction is a means of job creating opportunity. The only thing that is required for someone to work in this area is for them to be jobless and become a member of an association”.

The Procedure one should follow to obtain a sand mining license is:

1. Organized into association by organizers i.e. union associations“ offices or small and medium enterprise offices.
2. Applying to mining offices.

The duty of mines office in order to issue the mining license is

- They check the legality of the association (i.e. whether they are organized by organizing offices mentioned above).
- After proving the association to be legal the office delegate the mining locality requested by the association.
- The mining office writes a letter to the rural land administration and environmental protection office of the woreda to prove whether there is conflict over the requested mining site in order to issue the license for the licensee.
- If the rural land administration and environmental protection office gives consent that there is no conflict on the issue, the woreda mines office will charge the association to pay land tax of 50 birr and license fee of 100 birr for the one year they will be given the license.
- After the association pays that charge, the mines office issues the license. The license has:
  - Mining certificate
  - Agreement between the office and the association
  - The location map of the mining site

3. During the mining, the associations are obliged to sell the mineral only with the mining receipt given by the mining office. When the receipt pad given for the association is finished, the association is obliged to bring back the second copy of the receipts and pays the royalty fee (3% of the total sales) to the government.

Once the license is given to the associations, each individual gets a 4m span along the river to mine, no trespassing is allowed. Therefore, whatever quantity that person gets in the 4m span is his and has all the legal power to sell it.

## **4.2. Legal framework for Environmental Impact Assessment**

Even though all the applicable laws including the FDRE Constitution, Environmental Impact Assessment Law, Sectoral Laws indicate the relevance of Environmental Impact Assessment for any mining sector. The Federal Negarit Gazeta proclamation No. 678/2010- mining operation proclamation page 5421 (see annex B) states that “*except for reconnaissance license, retention license or artisanal mining license, any applicant for a license shall submit an environmental impact assessment and obtain all the necessary approvals from the competent authority required by the relevant environmental laws of the country.*” Therefore, according to the law set by this proclamation there is no need for the preparation and submission of EIA in the case of fine aggregate/ sand extraction.

## **4.3. Study Area**

Oromia region which is found in the central part of the country consists of eighteen zones from which the East Shoa is one of them. East Shoa the biggest sand extraction for city of Addis Ababa has twelve woredas (Adama, Adea, Adami Tulu, Jido Kombolcha, Bosat, Lume, Bora, Dugda, Liban, Cukala, Fantale and Gimbichu) under it but only the first ten have sand mining sites. The East Shoa zone as a whole contains 412 organized associations which contain 21,171 people under it out of which 19,439 are male and 1,732 are females. Out of the woredas the Lume woreda has been selected due to proximity reasons. Three sites who are legally licensed associations from this woreda have been visited these are: Ere Bisoma (referred to as site A), Gudetu (referred to as site B) and Ejersa Jebdu (referred to as site C).

#### **4.4. Sources of fine aggregate**

The sources of the fine aggregates in the Oromia region are of two types:

- a. River sand

The river sand, as the name describes, is basically found on the banks or beds of the river and mostly extracted during the dry season as it becomes difficult to do so in the wet seasons. The type of river may be that of perennial, which carry water throughout the year, or intermittent, which carry water during the wet season. All the three visited sites were of the intermittent river type.

- b. Sand accumulated due to erosion and through time covered by vegetation

In this case, the sands are buried under vegetation; therefore, in order to extract the sand, there is removal of the vegetation as well as the top soil. According to the interviews carried out, there are about six sites in this zone which are of this type of sand. The overburden varies from site to site. For example, in an area near Ziway in the Adami Tulu Edo Kombolcha woreda, more than two meters overburden has been encountered.

#### **4.5. Fine aggregate/ sand production process**

The production of sand follows a number of steps as mentioned in the literature section of this thesis. Below, discussion is made regarding the extraction of sand in the sites visited as well as from the output of the interviews.

##### **4.5.1. Exploration**

According to the interviews conducted, no exploration has been done for any of the sites. And no explorations are being done for sand mining sites, rather sand mining sites are pinpointed by trend - where there is a river, there is sand. It is the licensees who propose the place to the woredas instead of it being vice versa. There are no geologists in the woreda level and sand mining is administered by the woreda; therefore, no exploration is done. Hence, there is no know-how on the location, extent and value of the sand deposit.

### **4.5.2. Mining**

The mining process basically uses an artisanal technique which is chiefly a primitive way of extraction. The mining of the fine aggregate is done in the dry season in a moist or wet condition by open pit excavation. The excavation is carried out by making use of hand shovels and sometimes pick axe. No machineries are being used in any of the sites; everything is done by human force. Moreover, the site overburden which is mainly composed of silt, loam, clay, or combinations of the three has not been removed from the top of the sand formation. Exemplar pictures are shown in figure 7, 8 and 9.



Figure 7 Sand extraction in site A (picture taken by researcher).



Figure 8 Sand mining in site B (picture taken by researcher).



Figure 9 Sand extraction in site C (picture taken by researcher).

As it can be seen from the pictures above, in all the three sites, the extraction of sand is done in a traditional way using the human labor. The only equipment they use is the hand shovel. This approach is so old-fashioned compared to other countries' standards as seen above in the literature review section.

### **4.5.3. Processing**

The size and shape of sand must be uniformly graded in order to attain the desired output. To attain this uniformity, the sand is run through a processing plant. In all the three sites, there is no such thing as a processing plant; the sand mined is simply sold as it is.

In standards, the sand goes into different combinations of washers, driers, screens, and classifiers to segregate particle sizes; crushers to reduce oversized material; and storage and loading facilities. None of this has been seen in the sites visited.

It has been observed that the workers claim that they are washing the sand, when actually what they are doing is taking it out of the water bearing bed of the river (figure 10, 11 and 12). This is followed by piling it up and waiting for it to dry which in turn reduces the weight of the sand for transportation purpose, which they refer to as drying.



Figure 10 The so called Washing and Drying process in site A  
(picture taken by researcher).



Figure 11 The so called Washing and Drying process in site B  
(picture taken by researcher).



Figure 12 The so-called sand washing and drying in site C (picture taken by the researcher).

#### **4.5.4. Transporting**

Transportation, which is the key element of the supply system, is very primitive in all the three sites. The mode of transportation of the sand from the time it is mined to where access to vehicle is possible is done by means of a donkey, an exemplar picture is shown in figure 13. Then onwards, it is loaded onto dump trucks manually as shown in figure 14. The process is basically loading to a donkey by human labor, unloading it in a vehicle accessible place by human labor, and loading to vehicles by human labor. Therefore, one can easily understand how labor intensive the system is.



Figure 13 Sand unloading to a vehicle accessible place in site A (picture taken by researcher).



Figure 14 Sand loading to a dump truck from a vehicle accessible place in site B (picture taken by researcher).

#### **4.5.5. Reclamation**

Proclamation from the Negarit Gazeta (see annex B) regarding reclamation states that *„Except the holders of reconnaissance license, retention license or artisanal mining license, any licensee shall allocate funds to cover the costs of rehabilitation of environmental impact“*.

Reclamation, which is the end stage to a particular mining, requires planning way ahead. None of the sites have plans on what to do once they are done mining. These people have been mining at this place for over ten years now. Even though the license is only given for a year, the people have refused to leave the site. Can they really do this? Well they have, this can say something on how strict the rules are.

According to the interviews, all the sites in the East Shoa zone are active with the exception of one which has completed the extraction of the sand. The type of sand is one which has been accumulated due to erosion and through time was covered by vegetation. Even though there has been a lot of deforestation, change in topography, change in habitat, etc., no rehabilitation has been done and it is left abandoned.

## 4.6. Laboratory results for quality check

As mentioned above in section 3, methodology, laboratory tests for silt content and gradation were performed. The results are shown below.

### 4.6.1. Silt Content

A test on the silt content for the nine sand samples was made in the laboratory as shown in figure 15.



Figure 15 Silt contents of the nine sand samples (picture taken by researcher).

The results are displayed in table 3 along with a discussion on the compliance with the Ethiopian standards, i.e. the silt content should not exceed a value of 6% for it to be acceptable.

Table 3 Summarized test results for the computation of silt content of fine aggregate for all sites.

Sample Source	Silt content (%)	Allowed (%)	Remark
Site A sample 1	9.33	6	Not acceptable
Site A sample 2	7.14	6	Not acceptable
Site A sample 3	12.5	6	Not acceptable
Site B sample 1	30.77	6	Not acceptable
Site B sample 2	6.25	6	Not acceptable
Site B sample 3	6.25	6	Not acceptable
Site C sample 1	17.86	6	Not acceptable
Site C sample 2	10.63	6	Not acceptable
Site C sample 3	12.14	6	Not acceptable

As it can be seen from table 3, all the three samples for site A do not comply with the standard requirement. These are actually samples which the licensees claim to be washed. What could be the silt content of the unwashed ones?

Site B samples show non-compliance with the requirement. Even though the results are better for sample 2 and 3, they still do not fulfill the standard. The first sample which is referred to as unwashed sand has a 30% silt content! One can imagine the consequences that can occur by making use of sand with this amount of silt content. When making a purchase of the sand, the first question that is raised is whether you would like washed one or unwashed. This says something about what the unwashed implies! There are also cases where they combine the washed and the unwashed and refer it to as „Yetekelakele“ (mixed).

The results for the third site similarly do not comply with the standards. In this case also a silt content amounting 17.86% has been found.

#### 4.6.2. Sieve Analysis

As the fine-aggregate grading within the limits of ASTM C33 (AASHTO M 6/ Ethiopian standard) is generally satisfactory for most concretes, a test in the laboratory for the nine fine aggregate samples on sieve analysis was conducted and compared with the standards. This is displayed in table 4.

Table 4 Summarized test results for the computation of sieve analysis of fine aggregate for all sites.

Sieve size (mm)	9.5	4.75	2.36	1.18	0.6	0.3	0.15
Allowable cumulative passing range(%)	100	95-100	80-100	50-85	25-60	5 – 30 (AASHTO 10 – 30)	0 – 10 (AASHTO 2 – 10)
<b>Cumulative passing (%)</b>							
<b>Site A</b>							
Sample 1	99	98	97	93	72	14	1
Sample 2	97	94	88	76	46	9	1
Sample 3	99	96	92	79	42	6	1
<b>Site B</b>							
Sample 1	99	96	89	64	20	3	0
Sample 2	99	97	97	66	20	2	0
Sample 3	97	89	70	34	6	1	0
<b>Site C</b>							
Sample 1	99	97	93	87	72	15	1
Sample 2	99	95	89	81	61	13	1
Sample 3	99	95	88	77	54	12	1

The results for sample1 of site A show that they do not meet the criteria for the 1.18, 0.6 and 0.15 sieves. This implies that we need more particle size that retains on sieve no. 1.18 and 0.6. Moreover, there is retention of more than 45% between the 0.6 and 0.15 sieves which is against the compliance requirement.

The results for sample 2 of site A indicate that there is no compliance with the standard for the 4.75, 0.3 and 0.15 sieves. This suggests that we need less particle size that retains on sieve no. 4.75 and 0.3.

The results for sample3 of site A show that they do not meet the criteria for the 0.3 and 0.15 sieves. This implies that we need more particle size that retains on sieve no. 0.15.

A summarized graphical representation of the compliance of the samples for site A with the requirement is given in figure 16.

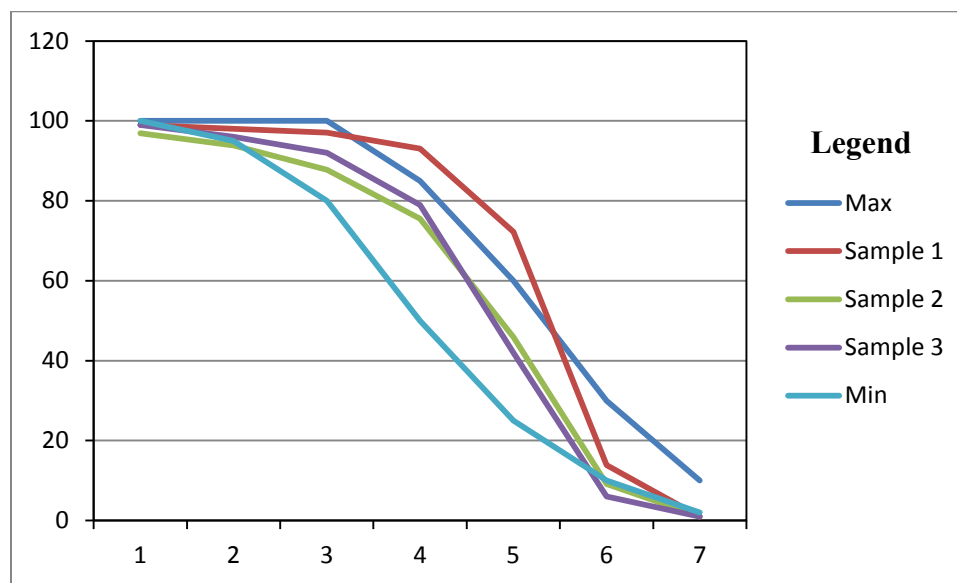


Figure 16 Summarized gradation of site A against Max and Min values.

The results for sample1 of site B indicate that there is no compliance with the standard for the 0.6, 0.3 and 0.15 sieves. This suggests that we need less particle size that retains on sieve no. 0.6 and 0.15.

The results for sample2 of site B show that they do not meet the criteria for the 0.6, 0.3 and 0.15 sieves. This implies that we need less particle size that retains on sieve no. 0.6 and more quantity that retains on the 0.15 sieve. In addition there is retention of more than 45% between the 1.18 and 0.3 sieves which is in contradiction to the compliance requirement.

The results for sample3 of site B indicate that there is no compliance with the standard for all the sieve sizes except for the 9.5. This suggests that we need less particle size that retains on sieve sieves.

A summarized graphical illustration of the samples for site B via the criteria is shown in figure 17 below.

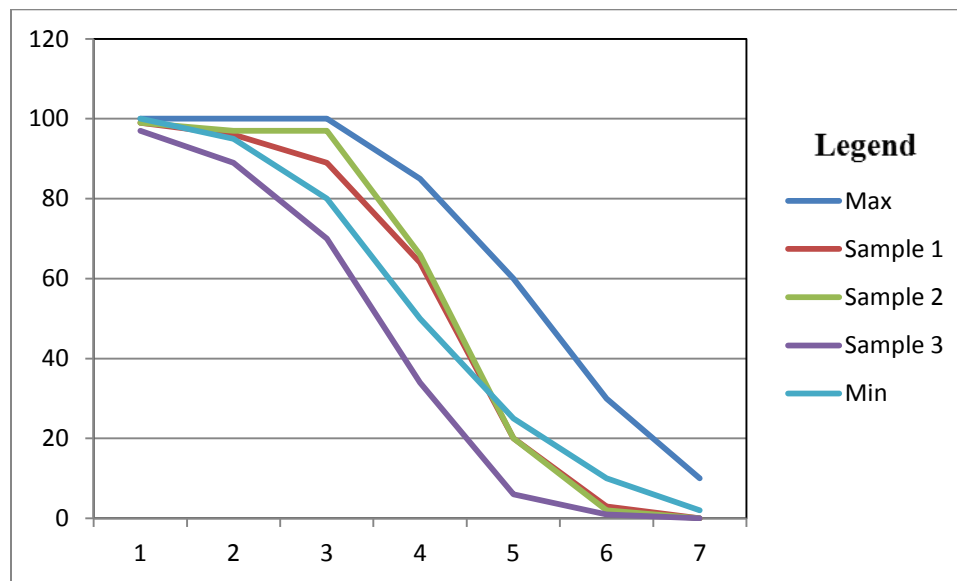


Figure 17 Summarized gradation of site B against Max and Min values.

The results for sample1 of site C show that they do not meet the criteria for the 1.18, 0.6 and 0.15 sieves. This implies that we need more quantity that retains on the 1.18 and 0.6 sieve. In addition there is retention of more than 45% between the 0.6 and 0.15 sieves which is in contradiction to the compliance requirement.

The results for sample2 of site C indicate that there is no compliance with the standard for the 0.6 and 0.15 sieve sizes. Moreover, there is more than 45% retention between the sieves 0.6 and 0.15 which the standards don't allow. This suggests that we need more particle size that retains on the 0.6 sieve.

The results for sample3 of site C show that they do not meet the criteria for the 0.15 sieve. This implies that we need more quantity that retains on the pan.

A summarized graphical representation of the compliance of the samples for site C with the requirement is given in figure 18 below.

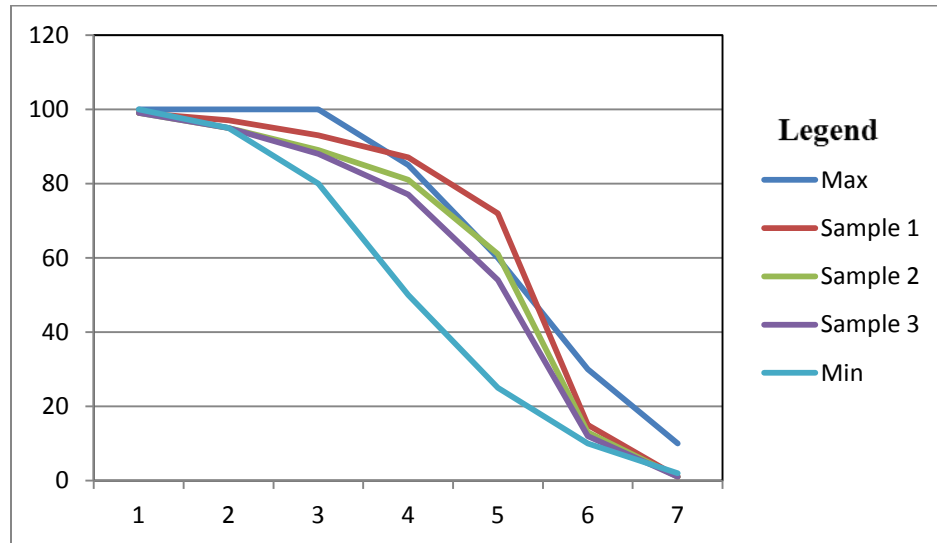


Figure 18 Summarized gradation of site C against Max and Min values.

### ***Fineness Modulus***

The fineness modulus of all the samples has been calculated following the sieve analysis calculation. In table 5 the values are displayed below with a discussion of the results.

Table 5 Summarized test results for the computation of fineness modulus of fine aggregate for all sites.

<b>Sample Source</b>	<b>Fineness Modulus</b>	<b>Allowed</b>	<b>Remark</b>
Site A sample 1	2.26	2.3 – 3.1	Not acceptable
Site A sample 2	2.89	2.3 – 3.1	Acceptable
Site A sample 3	2.85	2.3 – 3.1	Acceptable
Site B sample 1	3.29	2.3 – 3.1	Not acceptable
Site B sample 2	3.19	2.3 – 3.1	Not acceptable
Site B sample 3	4.03	2.3 – 3.1	Not acceptable
Site C sample 1	2.36	2.3 – 3.1	Acceptable
Site C sample 2	2.61	2.3 – 3.1	Acceptable
Site C sample 3	2.74	2.3 – 3.1	Acceptable

The results for site A show that two of the samples are in compliance with the requirement of ASTM C 33 (AASHTO M 6/ Ethiopian standards) and more on the coarser side. But sample1 indicated a value which is less than the minimum requirement, i.e. 2.3 which implies that it is too fine.

The calculation for site B indicates that all the samples are greater than the standard value, i.e. 3.1. This indicates that the samples are too coarse to be used in concrete.

The samples from the third site meet the requirement and their fineness modulus is as per the standard, i.e. between 2.3 and 3.1. While the first sample is very fine, the second one is medium and the last one coarse sand.

## **4.7. Environmental impacts**

During field observation, various environmental impacts such as floodplain degradation, habitat destruction, riparian zone damage, dust, collapsing riverbanks and sedimentation were observed. The following is an overview of the observed environmental impacts. They do not follow any given order.

### **4.7.1. Biological/ Ecological Impacts**

#### *Riparian Habitat, Flora and Fauna*

One obvious effect of sand extraction is the loss of riparian habitats and species. During the interviews, no one seemed to know about the species that exist in the water - whether they are still existing or lost. One of the workers stated that the fishes in the river attack their bare foot while they are working; he actually considered this as a good thing and mentioned that it is good for the fishes as they get to eat the leftovers from their foods. In my view, this is a negative impact as it is totally out of the natural way. Naturally, fishes feed on things in the water and not on human's leftovers and while the people are working, they are actually becoming an obstacle for the fishes. Instead of enjoying the nature, the fishes are forced to run for their lives.

The degradation of land was observed during the visit to the sites which has very much reduced the aesthetic value. Figure 19 shows a degraded land which has lost its aesthetic value.



Figure 19 Degraded land with lost aesthetic value (Picture taken by researcher).

The destruction of the soil profile destroys habitats both above and below the ground as well as within the aquatic ecosystem, resulting in the reduction in faunal populations. In figure 20, it can be seen that due to the mining, the roots of these beautiful trees have been exposed which will eventually mean the trees will dry out soon. We all know how long it takes for trees to grow this big; however it seems like no one actually cares!



Figure 20 Trees with exposed roots (Picture taken by researcher).

#### 4.7.2. Geological/physical Impact

##### *Stability of Structures*

During the visit to the sites, the sand structure where we were standing, which is close to where the water is was not stable (figure 21), the licensees warned us not to go near as the structure may collapse. Imagine if the warning was not given and what about those who are not warned? What about the donkeys, which are used for transportation, when they come near to drink water?

The collapsing of the riverbanks widens the river channel, reducing the channel depth. It also increases the sediment load and the magnitude of sedimentation as well as the turbidity downstream of the collapsed banks.



(a)



(b)

Figure 21 Unstable sand structure in the mining site (picture taken by researcher).

##### *Water Quality*

The increases suspended solids in the water at the mining site very much affect the water quality. The water in these areas is used for domestic use which significantly affects the population. Moreover, as the water becomes muddy, this prohibits fishes on seeing what they feed on.

### *Air quality*

The research displays that the air quality issue in the case of the mining is due to the stockpiling process, loading to trucks and mostly related with the ground abrasion when truck wheels kick up dust. Figure 22 shows dust blown in the air produced from vehicle wheels. Moreover, dust produced from uncovered or partially covered dump trucks is another factor that affects the air quality.



Figure 22 Blown dust in the air due to wheels of vehicle (picture taken by researcher).

### **4.7.3. Socio-economic Impact**

#### **Economic impact:**

Unlike the environmental impact it brings about sand mining has its own economic benefit. From the information obtained in the interview there were about 20 million birr sales for sand in the East Shoa zone for the year 2013. In other words this would mean an approximate sale of 288,000 m<sup>3</sup> in a year. The sales for Lume woreda alone were estimated to be around 1 million birr in a year amounting sales of 15,400 m<sup>3</sup> of fine aggregate.

#### **Social impact:**

The total employment in the East Shoa zone for the year 2013/2014 is 21,171 employees. The first site under study which is the Ere Bisoma has employee number of 207, the second site which is Gudetu has 125 people under it and the third site which is Ejersa Jebdu has 86 people employed in it. While for the Lume woreda in total there are 22 organized associations with 715 people working under it.

#### 4.7.4. Other impacts of sand mining include:

- a) Damage to roads: Due to heavy traffic resulting in increased sand transportation by sand loaded trucks, roads result in frequent damage and frequent repairs, thus affecting the road traffic, sometimes even prone to accidents due to the narrow roads. Extremely damaged roads during the visit are shown in figure 23.



(a)



(b)



(c)

Figure 23 Damaged roads in sand mining areas (picture taken by researcher).

- b) The research shows that the mining sites are located further passing residential areas. The inhabitants are being affected by noise and dust of the vehicles from these sand mines. Moreover, due to the damaged roads there is an increased use of unplanned access roads damaging the farm lands, damaging their crop.

- c) The study displays that there was a flood hazard in the area due to diversion of the canal which caused damage to crop agriculture and humanity as well as erosion of fertile land.

From the interviews, it has been found that the study area rivers are an input to the Awash basin which is found in the downstream due to the removal of the sand at these points the Awash basin is becoming accumulated with silt- siltation.

## **4.8. Production capacity and Sales price**

### **4.8.1. Production capacity**

The production capacity of the licensees basically depends on the strength and the performance of the individual person. From the interviews, an approximate production capacity of one person per day is around 2.8 meter cube (m<sup>3</sup>) of sand. This implies for a person to perform sales for a 14m<sup>3</sup> capacity car, that person requires six days if the weather is sunny. In addition, the poor domestic animal has to go back and forth 200 times in order to fill a 14m<sup>3</sup> capacity car.

### **4.8.2. Sales price**

The Oromia water mines and energy bureau in 2000E.C. set the sales price for sand to 70 birr per meter cube. However, the associations use different rates and do not strictly follow the rules. The sales are performed using a receipt from the woreda. Once the receipt sheets are full, the licensees are obliged to pay 3% royalty fee and 2% yearly tax. The study indicates that it is believed that 30% profit is obtained from the sales the licensees make. In addition to the sales price for the sand, the associations have a fixed price for loading to vehicles which is approximately 90 birr per meter cube - this is greater than the value of the sand.

During the research, a visit to Kality where trucks loaded with fine aggregate await for customers to buy was made. The price the sand is sold in this area for the same sand source is 6500 birr per 14 meter cube i.e. 464 birr/m<sup>3</sup>. So, who is actually benefiting in this scenario?

A simple estimation of the saving one can get from buying from the actual site instead of from Kality area is shown below.

- Base data:
  - Total distance from Addis Ababa is 83 kilometers.
  - 6 kilometers can be driven with 1 liter of gas.
  - Current gas cost as 18 birr.
  - Car rental cost as 1000 birr.
  - Driver's daily fee as 200 birr.
  - Other car expenses as 300 birr.
  - Cost of sand as 160 birr per m<sup>3</sup>.
- Calculation:
  - Total expense= fuel cost + car rental cost + Driver's fee + other car expense + cost of sand
$$= (83*3*2) + 1000 + 200 + 300 + (160*14m^3)$$
$$= \boxed{4238 \text{ birr}}$$

From this, one can easily understand that it is much cheaper for a person to buy sand from the actual mining site rather than from kality, a saving of around 2000 birr per the 14 m<sup>3</sup> can be attained i.e. 161 birr per m<sup>3</sup>, but it seems no one has realized this so far.

#### 4.9. Future prospects

Fine aggregate, being a naturally existing mineral, is found only in a limited amount. It may seem to many that we have more than enough of the resource at this point. However, the question is do we have enough now and will we have enough in the future? Denamo (2005) in his research titled *„Handling of concrete making materials in the Ethiopian construction industry,*’ researched the production method around Koka area which is found 90km from Addis Ababa and stated that “*Natural fine aggregate or sand is dredged from river beds in most parts of Ethiopia. Finely crushed aggregate is also used in some parts of the country where natural sand is not available. In most parts of the country, though the quality varies significantly one from the other, fine aggregate is available abundantly at least for the present.*”

In my opinion when talking about having enough we need to look at it in two perspectives, i.e. in terms of quality and quantity.

What quality of the fine aggregate is available? Having the fine aggregate alone is not enough; the quality is also an important factor. As shown above in section 4.6, we have observed that most of the sand samples did not fulfill the quality requirement - some were missing the gradations that are required and some contained too much silt for it to be used in concrete. The sources for obtaining the fine aggregates which comply with the requirement are limited in our country and also throughout the world.

As discussed in section 4.4, the major source of fine aggregate in our country is found from rivers and for the sand to be accumulated in the rivers, there has to be rain. This type of extraction is known as a rain fed extraction. Suppose there is no rain for one expected wet season, it would mean no sand to extract from the rivers as the one which existed has already been extracted in the dry season. Moreover, the accessibility to where sand exists is limited. In some sites, it might not be convenient to do the extraction. These two factors limit the quantity of the fine aggregate that we will be able to get.

Therefore, the future of sand is associated with what quality and quantity of sand we would like to obtain and very much dependent on what nature gives us. We have no guarantee that we will get enough sand in the future we should try to look into alternatives and use what we have now efficiently.

## 5. CONCLUSIONS AND RECOMMENDATIONS

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Concrete, which is one of the most commonly used construction material, is constituted of aggregates that make up the most part of it. Out of the aggregates, 30-40% by volume is taken up by fine aggregates. Most of the fine aggregates being used in the Ethiopian construction industry are those which occur in nature. This natural occurrence of the fine aggregates makes them to be subjected to a wide range of variability. The end product of our concrete is greatly affected by the input of our aggregate material. Therefore, it is important to give close attention to the production process of these fine aggregates and their compliance with the requirements.

Moreover, the production process of fine aggregates creates environmental challenges. As a society, we must develop an appropriate balance for sustaining both fine aggregate resources and environmental resources. Hence, this study was conducted based on these premises. The results found are summarized as follows.

### 5.1. Conclusions

It was found from the research that licensing in the East Shoa zone of Ethiopia is still in the primitive stage. The licensing only requires one to be unemployed and become an organized association member. No other criteria such as capability to maintain the site and reclaim it are set by the government. Moreover, the laws are not so strict that licensees are still in the job site even though the law only allows one to work in the extraction process only for one year. Unlike the developed world, the preparation of environmental impact assessment is not a requirement for sand mining sites which should not be the case.

The research has observed that the production process for fine aggregate in the Rift Valley area is still in the primitive stage and do not meet the developed world's standard.

There are no exploration works performed for fine aggregate. Mining is done by unemployed people manually. There are no machineries used in any stage of the production process. There is no processing for the mined fine aggregates; they are sold as they are. Transportation is done by making use of donkeys to all-weather roads and from then onwards dump trucks are being used. Quarry sites which have been closed are not reclaimed but just being left as they are- abandoned. All these have an implication on the quality of the fine aggregate produced and also the production capacity and the environmental management aspect. By making use of the exploration process, one can get a brief idea about the availability, replenishment rate, etc., giving a clear picture of the sites. By going through a good processing system, the quality of the produced mineral can be improved. Making use of mechanized system helps in increasing the production capacity.

It has been displayed from the research that the supply and demand are not in correlation for fine aggregate. The demand is much higher than what is being supplied. This comes from the production capacity of the workers i.e. each worker only produces approximately 2.8m<sup>3</sup> of fine aggregate per day. This should be looked into for the supply to improve.

Test results from the research have shown that the qualities of the fine aggregates are not in compliance with the code requirements. Moreover, the quality of different samples in the same site vary which invalidates the current practice of contractors, i.e. test is done only once and concrete mix is prepared based on the test result for all the fine aggregate delivered from the same site.

Knowledge on the environmental impacts that sand extraction brings about is hardly known by the licensees as well as the woreda workers. The environmental impacts observed during the research were impact on the Riparian Habitat, Flora and Fauna. The lands have been degraded and the sites have lost their aesthetic value. The soil profile has been destructed, leaving the roots of trees to be exposed.

Moreover, the results have shown that the mining of the fine aggregate has brought about an impact on the geology (physical). Some of the impacts are the loss of the stability of the structures, the decrease in water as well as the air quality.

The research has also shown that the other impacts of sand mining are the damage to roads, the use of unplanned access roads damaging the farm lands damaging their crop, diversion of the canal which caused damage to crop agriculture and humanity as well as erosion of fertile land and, siltation in the downstream areas, i.e. the Awash basin.

The best mitigation mechanism to overcome the impacts caused by fine aggregate production is the careful preparation and implementation of operational plan that foresees all the possible impacts that can take place.

It was found from the research that the economic benefit as well as the employment opportunity sand mining brings, despite its environmental impact, is great. The study shows that there were about 20 million birr sales for sand in the East Shoa zone for the year 2013. The sales for Lume woreda alone were estimated to be 1 million birr. The total employment in the East Shoa zone for the year 2013/2014 was 21,171 employees. And for the Lume woreda alone was 715.

The sales price at the sites is not expensive compared to the sales price in Kality or in Addis Ababa. It has been concluded that the most beneficiary bodies are not the workers/ licensees themselves but rather those selling in Kality or in Addis Ababa. It is much cheaper for a person to buy from the sand mining sites than from Kality or Addis Ababa.

The research has displayed that sand being a natural resource, there is no doubt there might be a shortage in the future whether it is shortage in terms of quality or quantity. The fact that it is rain fed and also the barrier of accessibility are some of the factors that limit the supply.

## 5.2. Recommendations

The followings are the major recommendations/suggestions drawn from the study.

### **In relation to fine aggregate production:**

- The production process of fine aggregate should incorporate all the steps starting from the exploration to the reclamation stage.
- Aggregate production should be modernized, instead of leaving it to be labor based.
- Processing plants should be introduced in the country that will in turn assist in obtaining a better quality of the product.
- Fine aggregate producers should guarantee the production of a product which is consistent and meeting the quality requirements.
- Responsible statutory bodies should impose standardization requirements on parties who are producing fine aggregates.
- Reclamation should be a mandatory action while the production is ongoing, as well as when the site closes down.

### **In relation to geology:**

- Geological engineering map of Ethiopia should be prepared as it is an important input to know the exact quantity of fine aggregate available.
- Investigations on fine aggregate occurrences and the formation along with the knowledge of the parent rock should be studied.
- All available fine aggregate sites should be identified and mapped.

### **In relation to environmental impact:**

- An integrated environmental assessment, management and monitoring program should be part of the sand extraction processes.
- Evaluate physical, chemical and biological effects of fine aggregate mining on a river basin scale, so that cumulative effects of sand extraction on the environment can be recognized.
- Knowledge transfer on the fact that fine aggregate production has environmental impacts is important.

- Thorough investigations should be done for active as well as closed sites on environmental impacts.
- Environmental impacts on the surrounding area should be identified and technical advice should be given to develop environmentally friendly situations.
- There is an urgent need for strengthening multidisciplinary studies on the sand mining rivers for providing adequate scientific information to river restoration and management activities.
- Taking all the precautions necessary to minimize the environmental impact of sand mining is important.
- Urgent maintenance should be done for those sites where the environmental impacts have severely affected them.

**In relation to standardization and research:**

- Fine aggregates should be standardized for the end product to acquire the required result.
- The quarry sites should be checked for compliance criteria, and should produce the same quality consistently.
- Alternatives to river sand for construction purposes should be examined and encouraged. Alternative to sand in construction industry should be researched and used like that of the M-sand, i.e. manufactured sand.
- Immediate steps should be taken to intensify research activities leading to the finding of suitable, low cost and easily available alternatives to river sand. Simultaneously, alternative building technologies with low sand / no sand content to be developed and promoted to rescue the rivers of the study area from further deterioration.
- The use of recycled materials should be promoted and encouraged. This will reduce the need to open new mines and help with the problem of overloaded landfills.

**In relation to concrete production:**

- The use of ready mix concrete should be sought for. Production of ready mix concrete should be encouraged and introduced in the Industry.

**In relation to regulations and responsibilities of statutory organs:**

- The government, industry, and the public must cooperate at the regional and local planning levels for sustainable fine aggregate extraction to be successful. Each of the primary stakeholders - government, industry, public, and other organizations must accept certain responsibilities. Government has the responsibility to develop the policies, regulatory framework, and economic incentives that provide the climate for success. Industry must work to be recognized as a responsible corporate and environmental member of the community. The public and non-governmental organizations have the responsibility to become informed about fine aggregate resource management issues. All stakeholders have the responsibility to identify and resolve sincere concerns by constructively contributing to a decision-making process that addresses not only their own but a wide range of objectives and interests.
- The quality of the fine aggregates should be rigorously followed and quality criteria set.
- Based on the construction earth materials type, mining criteria and techniques, mining rules and regulations should be applied.
- Strict rules should be set for the sales price to avoid the over pricing of fine aggregate in Addis Ababa.
- Thorough follow-up should be done on the sand extracting sites on the production, sales and environmental concerns.
- For tracking purpose, the Mines and Energy Bureau should keep data on the existing and closed sites on how much fine aggregate has been extracted, the land use, the economic return., and so on.

## 6. SUGGESTIONS FOR FUTURE WORKS

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- The impact of manufactured sand production on the environment.
- Assessment of sociological and ecological impacts of sand and gravel mining.
- Sustainable development using supplementary cementitious materials and recycled aggregate.
- Investigation of alternative concrete making materials in Ethiopia.
- Actual supply and demand gap of concrete making materials in the Ethiopian Construction Industry.
- Assessment of alternative sources of aggregates in Ethiopia.
- Assessment of suitability of the different types of fine aggregates available in Ethiopia for production of concrete.
- Prospects of using ready-mixed concrete in the Ethiopian Construction Industry.
- Assessment of concrete aggregate wastage in the Ethiopian quarrying industry.
- Assessment of artificial aggregates available in Ethiopia for concrete production.

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## **ANNEXES**

**ANNEX A**

No.	Check List
1.	<b>General</b>
	Who's the Owner
	Do they have license
2	<b>The source of the fine aggregate</b>
	Pit
	River
	Marine
3	<b>General Production process</b>
	Exploration
	Mining (open pit or dredging) equipment used to do work, has the overburden been removed
	Processing- washers, screens and classifiers, crushers, storage and loading facilities
	Transporting
	Reclamation
4	<b>Environmental Aspect</b>
	How was the site before the mining operation started?
	the removal of virtually all natural vegetation, top soil and subsoil to reach the aggregate underneath.
	Increased dust, noise, and vibrations
	Increased truck traffic near aggregate operations/ damage to roads
	Visually and physically disturbed landscapes and habitats
	Affected surface or groundwater
	Riparian Habitat, Flora and Fauna
	Stability of Structures
	Water Quality
	Land use(change the topography and stability of the landscape)
	Soil quality(where is the top soil is it saved for reclamation)
	Habitat and Aesthetic Beauty Degradation
	River system degradation
5	<b>Sales Related</b>
	How much does it cost per truck
	What is the expense/profit
	How much is sold per day
6	<b>Employment</b>
	How many people are in the job
7	<b>Sampling</b>
	Take three samples from different places

ANNEX B

Federal Negarit Gazeta

Proclamation No. 678/2010 Mining operations proclamation

<p><b>፶፱. ካሳ በፈቃድ ሰጪው ባለሥልጣን ስላሟ ወሰንበት ሁኔታ፡-</b></p> <p>፩/ ስለሚከፈለው ካሳ ስምምነት ላይ መድረስ ያልቻሉ እንደሆነ ባለፈቃድ ወይም ባለንብረት ፈቃድ ሰጪው ባለሥልጣን እንዲወስንላቸው በጽሁፍ ሊጠይቁ ይችላሉ።</p> <p>፪/ ፈቃድ ሰጪው ባለሥልጣን ካሳውን በመ ወሰን ሂደት ሁለቱ ወገኖች አሉን የሚሉትን ማስረጃና መከራከሪያ እንዲያቀርቡ በማድረግ፡-</p> <p>ሀ) ካሳውን የሚወስንበትን ተንና ቦታ በመገለጽ ለሁለቱም ወገኖች ያሳውቃል፤</p> <p>ለ) በተረጋገጠ ማስረጃና መከራከሪያ መሆን ረት ውሳኔ ይሰጣል፤</p> <p>ሐ) ውሳኔውን በጽሁፍ ያስፍራል፤ እና</p> <p>መ) የውሳኔውን ቅጽ ለሁለቱም ወገኖች ይሰጣል።</p>	<p><b>59. Determination of Compensation by the Licensing Authority</b></p> <p>1/ Either the licensee or the property owner may, where they are unable to reach an agreement on compensation to be paid, request in writing the Licensing Authority to determine the compensation.</p> <p>2/ In the process of determining compensation, the Licensing Authority shall allow both parties to present their evidences and arguments after which it shall:</p> <p>a) fix a place and date for conducting a determination of compensation and notify the parties of the same;</p> <p>b) make a determination on the basis of the evidences and arguments submitted;</p> <p>c) record its decision in writing; and</p> <p>d) give a copy of its decision to each party.</p>
<p style="text-align: center;"><b>ክፍል ሰባት፡</b> <b>ስለአካባቢ</b></p>	<p style="text-align: center;"><b>PART SEVEN</b> <b>ENVIRONMENT</b></p>
<p><b>፷. የአካባቢ ተፅዕኖ ግምገማና የመልሶ ማቋቋሚያ ፈንድ</b></p> <p>፩/ ከቅኝት፣ ከይዞ መቆየት ወይም ከባላላዊ የማዕድን ማምረት ፈቃድ በስተቀር ማንኛውም ፈቃድ እንዲሰጠው የሚጠይቅ አመልካች የአካባቢ ተፅዕኖ ግምገማውን አግባብ ላለው መሥሪያ ቤት በማቅረብ ማጸደቅ አለበት።</p> <p>፪/ ከቅኝት፣ ከይዞ መቆየት ወይም ከባላላዊ የማዕድን ማምረት ባለፈቃድ በስተቀር ማንኛውም ባለፈቃድ ለአካባቢ ተፅዕኖ መልሶ ማቋቋሚያ ወጪ መሸፈኛ የሚውል ፈንድ ይመድባል።</p> <p>፫/ የማዕድን ማምረት ባለፈቃድና እንደአ ግብዓት የማዕድን ምርመራ ባለፈቃድ ወይም ሌላ ሌላ ስለሚኖሩ ነዋሪዎች የግንባራ ልማት እቅድ መሳተፍና ለዚህ የሚያስፈልጉ ወጪ ይመድባል።</p> <p>፬/ ይህንን እንቅስቃሴ ለማስፈጸም ዝርዝር ጉዳይ በሚወጣ ደንብ ይወሰናል።</p>	<p><b>60. Environmental Impact Assessment and Rehabilitation Fund</b></p> <p>1/ Except for reconnaissance license, retention license or artisanal mining license, any applicant for a license shall submit an environmental impact assessment and obtain all the necessary approvals from the competent authority required by the relevant environmental laws of the country.</p> <p>2/ Except the holder of reconnaissance license, retention license or artisanal mining license, any licensee shall allocate funds to cover the costs of rehabilitation of environmental impact.</p> <p>3/ To be determined by the licensee area and by agreement, mineral licensee and, as appropriate, exploration licensee shall participate in community development plan of the peoples with in the license area, and shall allocate money for such expenses.</p> <p>4/ Particulars shall be determined by regulation to be issued for the implementation of this Article.</p>

## Annex C

### Onsite Picture survey

C1 Views of sand mining trend around the rift valley area.



**C2 Views of sand transporting trend around the rift valley area.**



**C3 Views of environmentally affected sand mining areas.**





**ANNEX D**

**Laboratory test results**

**D1** Test results for the computation of silt content of fine aggregate

**Site A**

<u>Site A Sample 1</u>	<u>Site A Sample 2</u>	<u>Site A Sample 3</u>
A = 7ml	A = 5ml	A = 10ml
B = 75ml	B = 70ml	B = 80ml

Where:

A = amount of silt deposited above the sand

B = amount of clean sand

**Calculation:**

**Silt content (%) =  $\frac{A}{B} * 100$ .....Equation 1**

**1. Sand for Site A Sample 1**

$$Silt\ Content = \frac{7}{75} X 100 = 9.33\% > 6\% \quad Not\ OK!$$

**2. Sand for Site A Sample 2**

$$Silt\ Content = \frac{5}{70} X 100 = 7.14\% > 6\% \quad Not\ OK!$$

**3. Sand for Site A Sample 3**

$$Silt\ Content = \frac{10}{80} X 100 = 12.5\% > 6\% \quad Not\ OK!$$

**Site B**

<u>Site B Sample 1</u>	<u>Site B Sample 2</u>	<u>Site B Sample 3</u>
A = 40ml B = 130ml	A = 10ml B = 160ml	A = 10ml B = 160ml

Where:

A = amount of silt deposited above the sand

B = amount of clean sand

**Calculation:**

$$\text{Silt content (\%)} = \frac{A}{B} * 100$$

**1. Sand for Site B Sample 1**

$$\text{Silt Content} = \frac{40}{130} X 100 = 30.77\% > 6\% \quad \text{Not OK!}$$

**2. Sand for Site B Sample 2**

$$\text{Silt Content} = \frac{10}{160} X 100 = 6.25\% > 6\% \quad \text{Not OK!}$$

**3. Sand for Site B Sample 3**

$$\text{Silt Content} = \frac{10}{160} X 100 = 6.25\% > 6\% \quad \text{Not OK!}$$

**Site C**

<u>Site C Sample 1</u>	<u>Site C Sample 2</u>	<u>Site C Sample 3</u>
A = 25ml B = 140ml	A = 17ml B = 160ml	A = 17ml B = 140ml

Where:

A = amount of silt deposited above the sand

B = amount of clean sand

**Calculation:**

$$\text{Silt content (\%)} = \frac{A}{B} * 100$$

**1. Sand for Site C Sample 1**

$$\text{Silt Content} = \frac{25}{140} * 100 = 17.86\% > 6\% \quad \text{Not OK!}$$

**2. Sand for Site C Sample 2**

$$\text{Silt Content} = \frac{17}{160} * 100 = 10.63\% > 6\% \quad \text{Not OK!}$$

**3. Sand for Site C Sample 3**

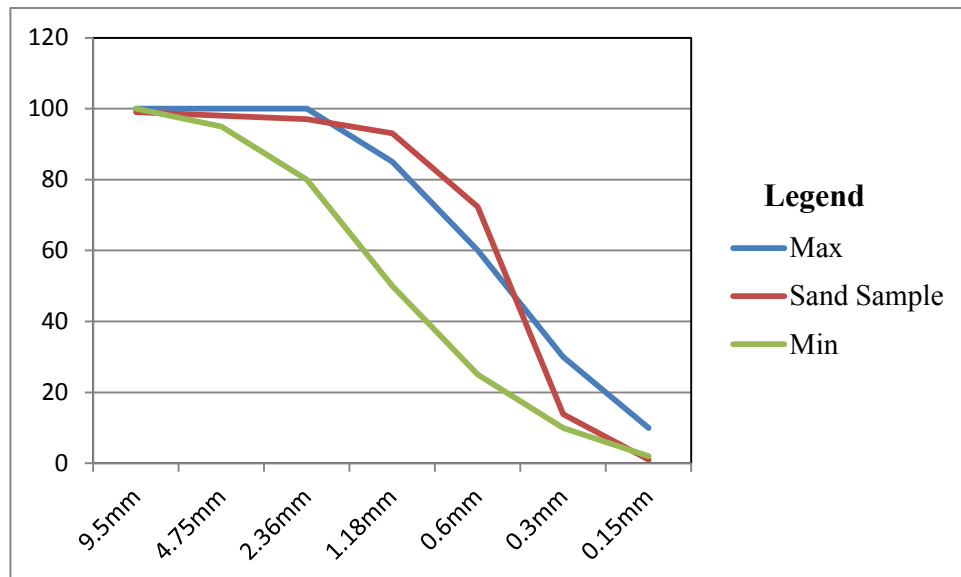
$$\text{Silt Content} = \frac{17}{140} * 100 = 12.14\% > 6\% \quad \text{Not OK!}$$

**D2 Test result for the computation of Sieve analysis**

**Fine aggregate grading for Site A Sample 1**

<b>Sieve size (mm)</b>	<b>Weight of Sieve (gm)</b>	<b>Wt. Of sieve and retained (gm)</b>	<b>Weight Retained (gm)</b>	<b>Percentage Retained (%)</b>	<b>Cumulative Coarser (%)</b>	<b>Cumulative Passing (%)</b>
9.5	585	590	5	1	1	<b>99</b>
4.75	430	435	5	1	2	<b>98</b>
2.36	385	390	5	1	3	<b>97</b>
1.18	355	375	20	4	7	<b>93</b>
0.6	325	430	105	21	28	<b>72</b>
0.3	305	600	295	58	86	<b>14</b>
0.15	275	340	65	13	99	<b>1</b>
Pan	255	260	5	1	100	
			505		226	

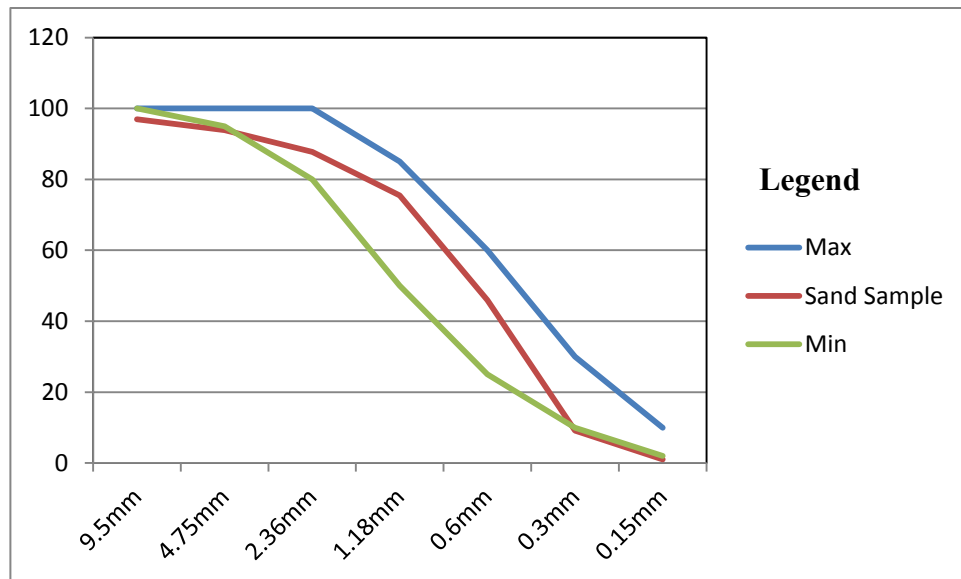
**Gradation of Sample 1 of site A against Max and Min values**



**Fine aggregate grading for Site A Sample 2**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	600	15	3	3	<b>97</b>
4.75	430	445	15	3	6	<b>94</b>
2.36	385	415	30	6	12	<b>88</b>
1.18	355	415	60	12	24	<b>76</b>
0.6	325	470	145	30	54	<b>46</b>
0.3	305	485	180	37	91	<b>9</b>
0.15	275	315	40	8	99	<b>1</b>
Pan	255	260	5	1	100	<b>0</b>
			490		290	

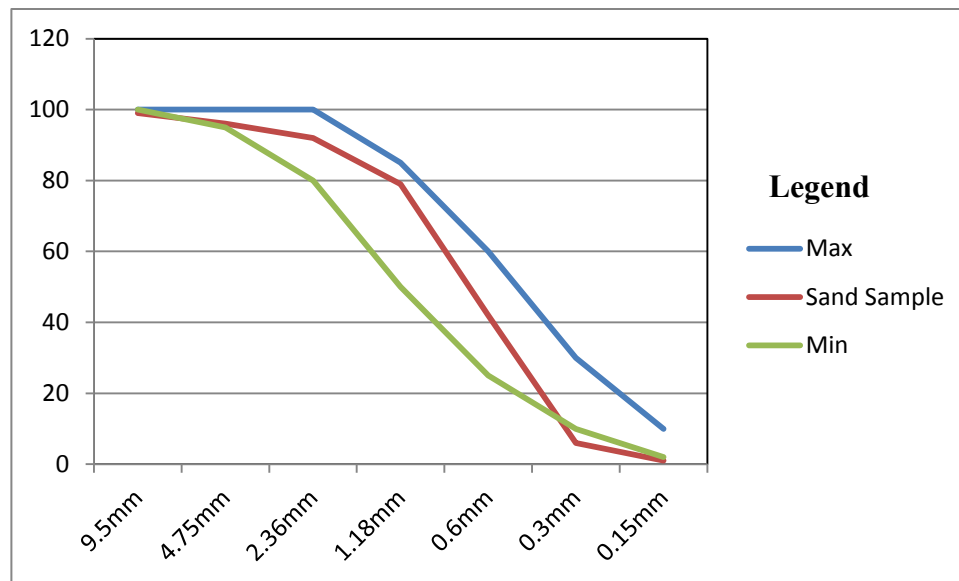
**Gradation of Sample 2 of site A against Max and Min values**



**Fine aggregate grading for Site A Sample 3**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	445	15	3	4	<b>96</b>
2.36	385	405	20	4	8	<b>92</b>
1.18	355	420	65	13	21	<b>79</b>
0.6	325	510	185	37	58	<b>42</b>
0.3	305	485	180	36	94	<b>6</b>
0.15	275	300	25	5	99	<b>1</b>
Pan	255	260	5	1	100	<b>0</b>
			500		285	

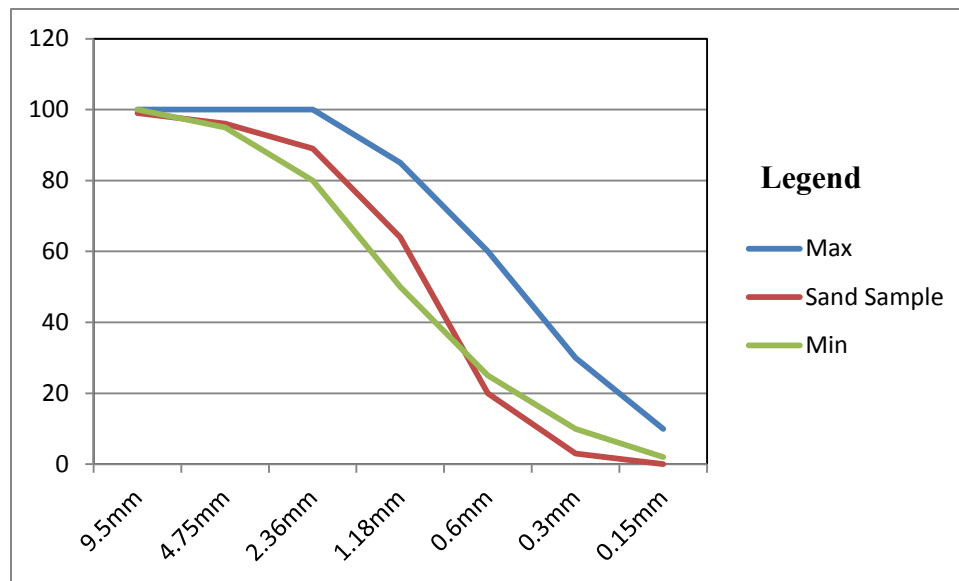
**Gradation of Sample 3 of site A against Max and Min values**



**Fine aggregate grading for Site B Sample 1**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	445	15	3	4	<b>96</b>
2.36	385	420	35	7	11	<b>89</b>
1.18	355	480	125	25	36	<b>64</b>
0.6	325	545	220	44	80	<b>20</b>
0.3	300	385	85	17	97	<b>3</b>
0.15	275	290	15	3	100	<b>0</b>
Pan	255	255	0	0	100	<b>0</b>
			500		329	

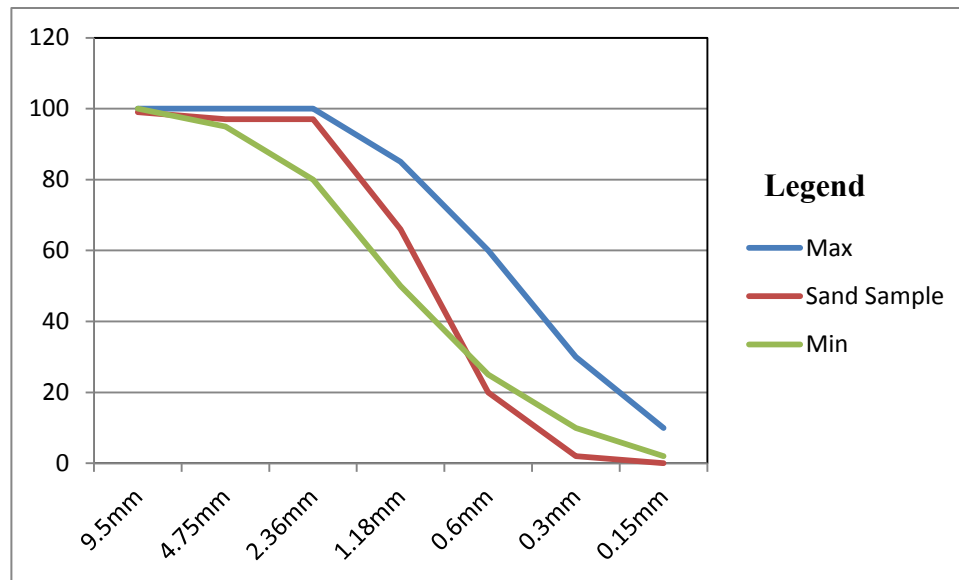
**Gradation of Sample 1 of site B against Max and Min values**



**Fine aggregate grading for Site B Sample 2**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	440	10	2	3	<b>97</b>
2.36	385	385	0	0	3	<b>97</b>
1.18	355	510	155	31	34	<b>66</b>
0.6	325	555	230	46	80	<b>20</b>
0.3	305	395	90	18	98	<b>2</b>
0.15	275	285	10	2	100	<b>0</b>
Pan	255	255	0	0	100	<b>0</b>
			500		319	

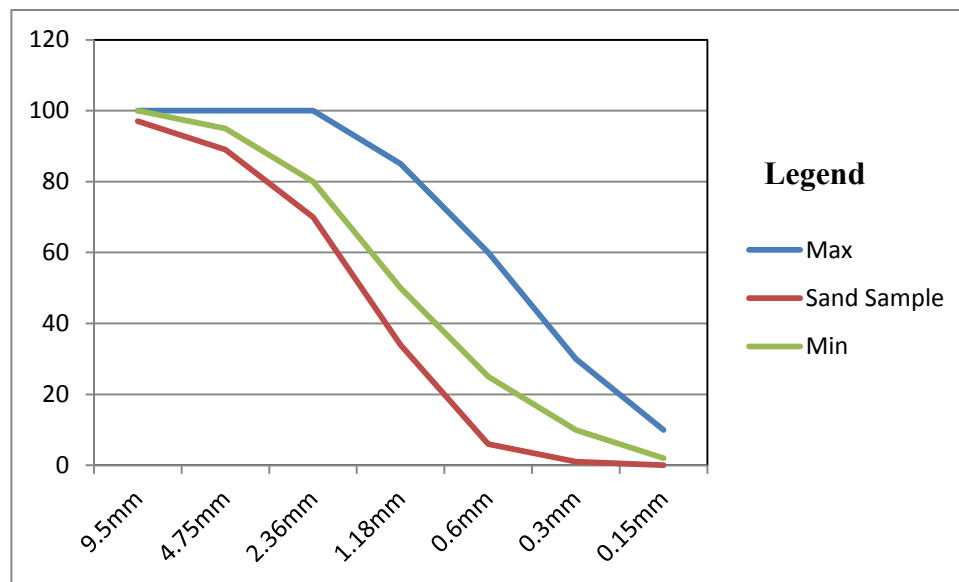
**Gradation of Sample 2 of site B against Max and Min values**



**Fine aggregate grading for Site B Sample 3**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	600	15	3	3	<b>97</b>
4.75	430	470	40	8	11	<b>89</b>
2.36	380	475	95	19	30	<b>70</b>
1.18	355	535	180	36	66	<b>34</b>
0.6	325	465	140	28	94	<b>6</b>
0.3	305	330	25	5	99	<b>1</b>
0.15	275	280	5	1	100	<b>0</b>
Pan	255	255	0	0	100	<b>0</b>
			500		403	

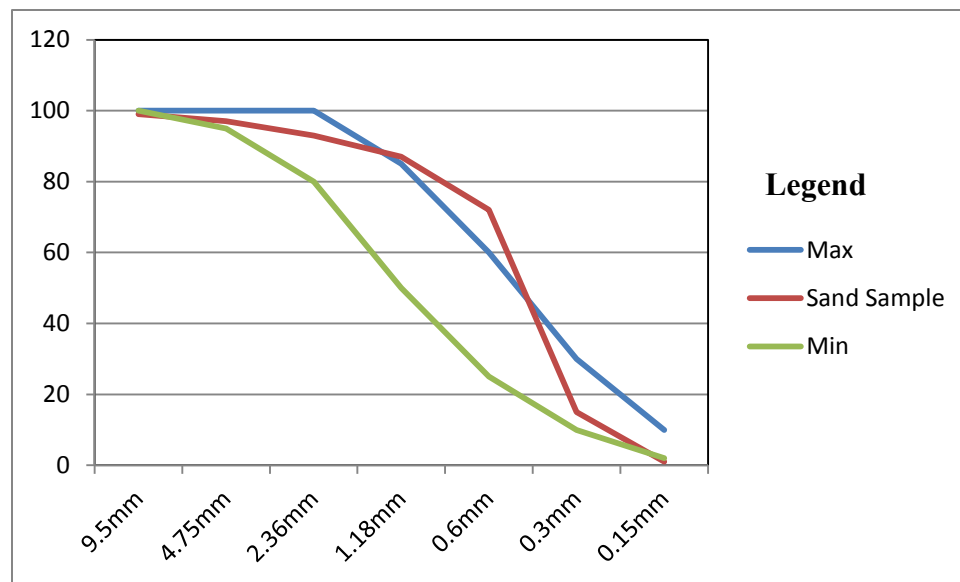
**Gradation of Sample 3 of site B against Max and Min values**



**Fine aggregate grading for Site C Sample 1**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	440	10	2	3	<b>97</b>
2.36	380	400	20	4	7	<b>93</b>
1.18	355	385	30	6	13	<b>87</b>
0.6	325	400	75	15	28	<b>72</b>
0.3	305	590	285	57	85	<b>15</b>
0.15	275	345	70	14	99	<b>1</b>
Pan	255	260	5	1	100	<b>0</b>
			500		236	

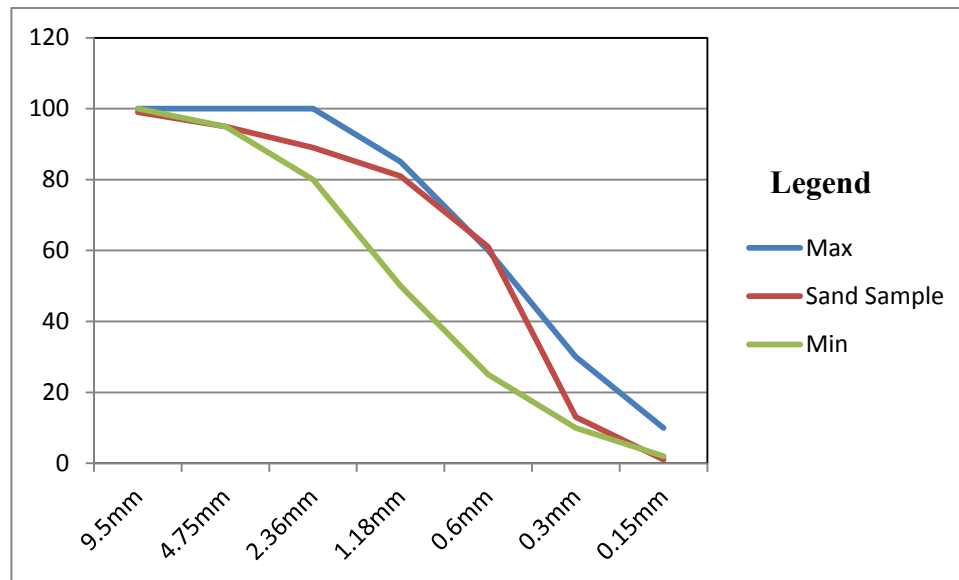
**Gradation of Sample 1 of site C against Max and Min values**



**Fine aggregate grading for Site C Sample 2**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	450	20	4	5	<b>95</b>
2.36	380	410	30	6	11	<b>89</b>
1.18	355	395	40	8	19	<b>81</b>
0.6	325	425	100	20	39	<b>61</b>
0.3	305	545	240	48	87	<b>13</b>
0.15	275	335	60	12	99	<b>1</b>
Pan	255	260	5	1	100	<b>0</b>
			500		261	

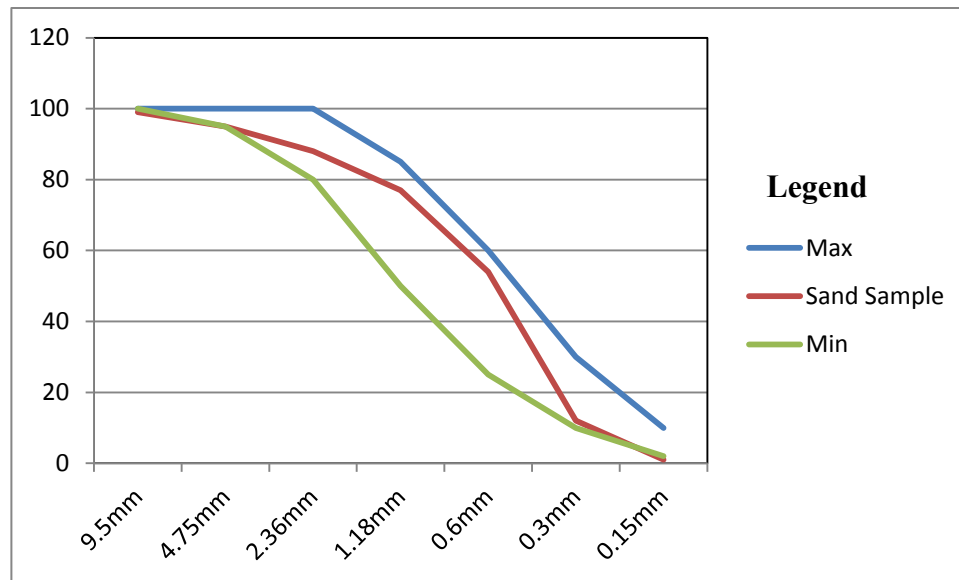
**Gradation of Sample 2 of site C against Max and Min values**



**Fine aggregate grading for Site C Sample 3**

Sieve size (mm)	Weight of Sieve (gm)	Wt. Of sieve and retained (gm)	Weight Retained (gm)	Percentage Retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	585	590	5	1	1	<b>99</b>
4.75	430	450	20	4	5	<b>95</b>
2.36	380	415	35	7	12	<b>88</b>
1.18	355	410	55	11	23	<b>77</b>
0.6	325	440	115	23	46	<b>54</b>
0.3	305	515	210	42	88	<b>12</b>
0.15	275	330	55	11	99	<b>1</b>
Pan	255	260	5	1	100	<b>0</b>
			500		274	

**Gradation of Sample 3 of site C against Max and Min values**



**D3 Fineness modulus computation**

**Calculation:**

$$F.M = \frac{\sum \text{cumulative coarser } (\%)}{100} \dots\dots\dots \text{Equation 2}$$

Where:

F.M. = the fineness modulus of the aggregate

**Fineness modulus for Site A samples**

**1. F.M for Site A sample 1**

$$= \frac{226}{100} = 2.26$$

**2. F.M for Site A sample 2**

$$= \frac{290}{100} = 2.89$$

**3. F.M for Site A sample 3**

$$= \frac{285}{100} = 2.85$$

**Fineness modulus for Site B samples**

**1. F.M for Site B sample 1**

$$= \frac{329}{100} = 3.29$$

**2. F.M for Site B sample 2**

$$= \frac{319}{100} = 3.19$$

**3. F.M for Site B sample 3**

$$= \frac{403}{100} = 4.03$$

**Fineness modulus for Site C samples**

**1. F.M for Site C sample 1**

$$= \frac{236}{100} = 2.36$$

**2. F.M for Site C sample 2**

$$= \frac{261}{100} = 2.61$$

**3. F.M for Site C sample 3**

$$= \frac{274}{100} = 2.74$$

**DECLARATION**

I, the undersigned, declare that this thesis is my original and has not been presented for a degree in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

Name	Yasmin Yusuf
Signature	
Place	Addis Ababa University, Addis Ababa Faculty of Technology
Date of submission	November 2014

This thesis has been submitted for examination with my approval as a University advisor.

Name	
Signature of the Advisor	
Date	