Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Investigating the Factors That Affect the Quality of River Sand in the Outskirts of Woldia Town

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

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Declaration

I, the undersigned, declare that this research is my original work performed under the supervision of my research advisor Abebe Dinku (Prof Dr. Ing) and has not been presented as a thesis for a degree in any other university. All sources of materials used for this thesis have also been properly acknowledged.

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Abbreviation and acronym

AASHTO - American Association of State Highway and Transportation Officials

ACI - American Concrete Institute

ASTM - American Society for Testing and Materials

BS - Bulking of Sand

CS - Compressive Strength

DOE – Department of Environment

ES - Ethiopian Standard

FM - Fineness Modulus

GPS - Global Positioning System

OI – Organic Impurity

OPC - Ordinary Portland Cement

PPC - Pozzolana Portland Cement

PV - Percentage Void

SC - Silt Content

SG - Specific Gravity

UW - Unit Weight

WA - Water Absorption

Abstract

Concrete is the widely used construction material made up of different constituents which later determine the property of final products. Since about 75% of the concrete matrix is made up of aggregate particles, the properties and strength of concrete is mainly affected by the nature and proportions of fine and coarse aggregates. This research was focused on assessing the potential factors affecting the quality of sand in the rivers around Woldia town which are the main sources of sand for the construction projects of the north Wollo zone and other towns of the Amhara region. In collecting sand samples from the exposed scenario, each single external factor was considered and tested by field test for its effect on the sand property. Based on the results of field tests, the potential factors affecting the properties of river sand were identified and further examined with different laboratory tests. The laboratory results of river sand samples collected from both controlled and exposed scenarios were interpreted. In the sand source rivers, there were external factors affecting sand properties with various degree of influence. The human, animal and truck action; soil, leaves and flora; and water flow of the river has considerable effect on the properties of river sand. While detergent and sewage from the town shows slight effect on the properties of sand. In order to know the effect on the compressive strength of concrete, the C25 concrete specimens were produced and tested for both controlled and exposed scenarios. Based on the existing factors in the sand source rivers, the research recommends the possible ways of treatment which helps to produce a consistent product.

Keywords

Fineness modulus, organic impurity, silt content, unit weight, standardization, factors of sand quality

1. Introduction

1.1. Background of the study

Construction materials are the physical input resources in the production of different physical infrastructures for the needs of the society by which the lifestyle of human beings can be improved. Infrastructures are solid artifacts which are fixed component of our environment built artificially by human beings. In constructing infrastructures different natural and artificial resources are used for achieving an acceptable quality, while responsible bodies shall choose good quality material.

Conventionally concrete is one of the most widely used man-made construction materials in the world, which is a mixture of cement, sand, and aggregate and its quality are affected by the properties of those ingredients. From the ingredients of concrete fine and coarse aggregates is an essential component which constitutes 65-75% of the total volume (Wiliam, et al., 2005). In concrete production, aggregates are needed to repair existing infrastructure, create new infrastructure for the country's growing population and meet the demands of changing lifestyles by good quality buildings and highways. The achievement level of these demands is dependent on the availability of large supplies of good quality aggregates. According to the United Nations environment program report in 2016, the annual production of aggregate worldwide totals about 16.5 billion tons. This values more than $70 billion, which in turn makes aggregate production one of the most important mining industries in the world.

In concrete production, ingredient quality has a great effect on the property of the final output. The quality of the aggregates is dependent on their physical properties, production process, handling and storing methods and other external factors. The methods of production in the place of extraction and ways of selecting materials source has a considerable effect on the quality of aggregate and further on the quality of concrete produced using it. In order to have a product that fits with the standards, the producers and the government should consider these parameters from the beginning of producing both fine and coarse aggregates rather trying to get a good quality on the raw materials which already lose its quality by different factors in production storing and handling processes (Denamo, 2005).

In order to ensure the concrete production process consistent with a prerequisite quality requires a consistent source, grading, absorption and moisture content of fine aggregate. Further, to ensure that the proper quality of fine aggregate is present, reliable sources, organized delivery, good storage and batching fine aggregate are essential. In the usage of fine aggregates, testing each package of fine aggregates for the requirements of the standard cannot be necessary, identifying the nature and environmental conditions of the sources and periodical sampling can be applied (Ethiopian Standard, 2005).

In Ethiopia, the most commonly used fine aggregate is river sands, however, crashed and pit sand is adopted in some places where natural sand is not available easily. Even though natural aggregates are widely distributed throughout the country, it is not necessarily available for use within the required standardized assortment. In some areas, natural sand may not meet the quality requirement of the standard by the presence of impurities because of poor production systems and other factors as well. Furthermore, an area can contain abundant sand which is suitable for the projected purpose, but its inconsistent properties that are caused by human and environmental factors may limit its usage and production.

The property of river sand in the production place can be affected by different factors. These factors can be grouped in two types which are; human factors which are different activities of the community including production system, waste removal practice and releasing of detergent and sewage from the towns, while environmental factors include nature of soils and weather condition of the area (Belete, et al., 2017). Therefore, identifying the factors and the extent of the effect on the quality of sand is essential to obtain the right type and good quality sand in the site, because aggregates form the main matrix of concrete (Wiliam, et al., 2005; Abebe, 2005). Despite their purpose, using these natural resources without assessing the exposedness and the extent of change in property by different external factors raises a concern about the failures of different construction works.

1.2. Statement of the problem

The consumption of construction materials in Ethiopia is increasing tremendously from time to time, due to the increase in demand for different infrastructures. Testing of material's quality is not only for accepting or rejecting materials in the construction process but also to propose which material is suitable for specified work. So that naturally available as well as artificially produced material shall be checked for the necessary standard properties before consuming them in construction projects. However, testing and distinguishing the materials as unsuitable is senseless in the idea that construction materials are available in scarce amounts. So that properly processing the available materials and keep it from different factors to have a required quality is advisable. So that the proper usage of the available river sand by preventing quality reduction due to external factors is advisable (Abebe, 2005; Anteneh, 2017; ACI, 2003).

According to past researches, the quality of sand in the rivers of the north Wollo zone is acceptable and supplied in many parts of the Amhara region for its ignorable silt and organic impurities, though the particles of the sand in most rivers of the area is poorly distributed. Even though the area has high potential that is anticipated to supply the sand demands for the developing construction industry of the country, the production process is undergone with a traditional ways by which the quality of sand and the safety of workers are not considered. In addition to sand production, the rivers are widely used as agricultural irrigation, car washes, dumping places of wastes and recreation areas (Belete, et al., 2017). These activities, as well as the environmental factors, have their own effect on the properties of sand produced from the rivers. The cloth and car washes and wastes removed from the villages can increase the organic impurity of river sand, while discourteous access of humans and animals can breakdown the particle and affect the gradation and fineness modulus of river sand. These practices which limit the production of consistent and trustworthy sand becomes critical issue with the developing of towns in the area of production. In this regard, this research was carried out to identify and control the factors that can change the property of sand and further the compressive strength of concrete.

1.3. Research questions

The research questions of this study were;

- What are the factors affecting the properties of river sand in the outskirts of Woldia town
- What are the effect of different practices on the properties of river sand in the outskirts of Woldia town

- What are the effect of sand exposed to different factors on the compresive strength of concrete
- What are the recommended methods of treatment for river sand exposed to different practices

1.4. Objectives

1.4.1. General objective

To investigate the factors that affect the properties of river sand in the outskirts of Woldia town.

1.4.2. Specific objectives

The specific objectives of this study are;

- To assess the change in sand property by different factors
- To indicate the effect of different factors of sand in compressive strength of concrete
- To suggest the possible treatment ways of exposed river sand

1.5. Significance of the study

The results of this study have great importance in shaping the sand production system, and other local activities around sand source rivers. Since the factors affecting the sand properties and the possible ways of preservation were interpreted according to the ease of implementation, acceptance and feasibility, the producers and governmental bodies can make the quality of river sand consistent and trustworthy by the consumers. In addition, this research will help to add a scientific concept that aims at controlling the factors before the sand has affected rather than treating river sand exposed in different uncontrolled factors.

Generally, this study will have great importance for sand producers, consumers and regulatory bodies to use the river sand efficiently by keeping from the external factors and can be used as a reference for future materials related studies.

1.6. Scope of the study

Aggregates can be classified into two major groups based on their particle size, these are fine and coarse aggregates. In addition, the fine aggregate can be divided into natural and manufactured based on the system of production. Further, natural fine aggregates can be grouped as pit sand, river sand, and marine sand by considering their sources. This study has focused mainly on assessing the factors that affect the quality of sands in the Production Rivers of Alawuha, Golina, Hormat, Mersa and Tikurwuha which are located in North Wollo zone of Amhara region. In addition to the quality of sand, the prolonged effect on the compressive strength of concrete produced using these sand has been assessed and examined according to the expected value with respect to different standards.

1.7. Limitation of the research

Although the research has achieved its objectives by taking critical measures, there were considerable limitations in collecting the samples for the laboratory tests. The two main limitations in doing this study was;

- More than one factor exists in some sample collecting river points.
- The effect of the factors were changing with time, weather condition and activities in the area

2. Literature review

2.1. Introduction

In the construction industry, materials are the main resources that are needed with a high degree of variation in their nature, availability and physical and chemical properties. Concrete is a mixture of cement, water, fine aggregate (sand) and coarse aggregate (gravel or crushed rocks) in which the cement and water have hardened by a chemical reaction called hydration, to form a binder for the aggregate which are considered as non-reactive materials. In addition to the above other materials are often incorporated, such as cement replacement materials and admixtures. From those widely used construction materials aggregates are the major and are naturally available all over the world, though these cannot be necessarily available with reasonable quality and in a demanded area. Fine and coarse aggregates generally occupy 60%-70% of concrete (70%-80% by volume) and strongly influence the property of fresh and hardened concrete, mix proportions and economy (Abebe, 2005).

Concrete is not just a modern construction material that was used as a material with different purposes in many civilizations and cultures for several hundred years. Many scholars agree that the oldest concrete was discovered in Israel about 7000bc, which was produced by mixing burnt limestone with water and stone to be used for flooring. A similar concrete product was also used in ancient Roman civilization during the second century BC, though it was considered as the first hydraulic cement concrete which was capable of hardening in water and insoluble. The cement used in this concrete product was a mixture of lime and volcanic ash from a source near pozzolana, by which many of the great Roman structures were constructed. Lime concretes were used in some structures of thick wall castles and other fortifications but not until the industrial revolution in the second half of the eighteenth century because of the revival of interest in materials achieve significant development. In addition, the mortal required by joseph Smeaton in 1756 and the roman cement which is developed and patented by James Parker in the 1790s has their own role on the cement concrete development of the modern technology (Illston, et al., 2010).

In the period at which Roman cement and other similar type materials produced, leads to the advancement of using raw materials which were a mixture of clay and calcareous materials resulting in a patenting of portland cement by Joseph Aspdin in 1824. In the process of portland cement production, clay and burnt limestone mixture were calcined until carbon dioxide was fully removed and fine powder products obtained the hydraulic cementitious properties. The name Portland cement was given to the product because of Aspdin considers the hardened product to have a property of portland stone (Illston, et al., 2010).

In most cases, the constituents of the hydraulic cement are essentially the same, though the refinements, the amount of calcining temperature, grinding level and knowledge of the cement improvements have its own effect to rapidly increase the quality and consistency of cement products. For the last century, the majority of vast construction structures were done by using portland cement concrete as a principal material, though there are considerable variety and types of cement and other alternative materials. It is clear that the availability of different types of cement, sand, and aggregates in the world makes concrete to be produced in widely different ranges of properties required by the consumers (Illston, et al., 2010).

It is generally accepted that the poor quality single material could affect the total construction work and may lead to failure so that identifying the quality of construction materials helps to construct the proposed construction projects with good quality. Further in achieving the required quality of naturally available materials, investigating the factors in the materials production area is a vital requirement.

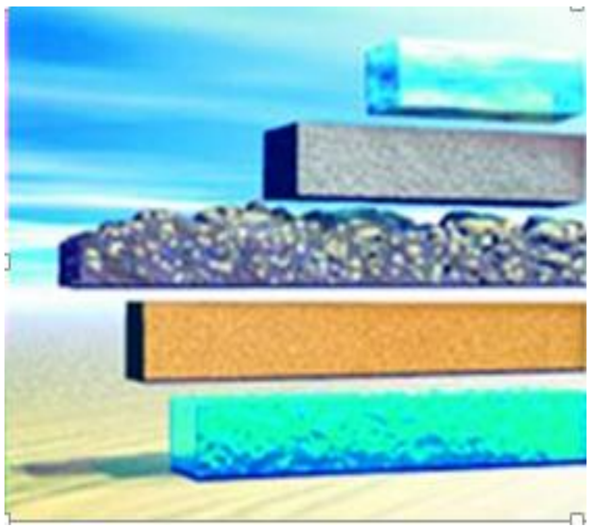
2.2. Cement concrete

2.2.1. Constituents of concrete

Concrete is a composite material which is produced from a binding material and an inert mineral filters which are embedded in the binding materials. In a normal cement concrete, the binding agent is cement paste which is a hydraulic mix of cement and water and the inert materials are aggregates that are graded from the coarse fragment of stones to fine particles. In addition to aggregates and binding agents admixtures can be used to improve the required special properties of concrete products (George, et al., 1965), as cited in (Abebe, 2005)). In the production process of cement concrete, the proportion of ingredients can be fixed by the following requirements;

- In the plastic state, the concrete shall be workable and placeable
- In hardened state possess strength and durability for the required purpose
- Achieve acceptable quality with a reasonable minimum cost

The cement paste is a mixture of cementitious materials, water, and entrapped air or purposely entrained air. The paste constitutes about 25% to 40% of the total volume of cement concrete. As shown in Figure 2.1 that the absolute volume of cement is usually between 7% and 15% and the water between 14% and 21%. The amount of air air-entrained concrete ranges from about 4% to 8% of the volume. Since aggregates make up about 60% to 75% of the total volume of concrete, evaluation of aggregate type, physical and chemical property, and size gradation is important (Steven, et al., 2011).



- Up to 8% air
- 7-15% cement
- 60-75 aggregate both (coarse aggregate and fine aggregates)
- 14-21% of water

Figure 2.1 Range in the proportion of materials used in concrete, by absolute volume (Steven, et al., 2011)

Concrete aggregates should contain particles with adequate strength and resistance to exposure and be free from materials that can cause deterioration of concrete products. Well-graded aggregate particles have the advantages of economical and efficient use of the cement paste. The property of concrete in both fresh and hardened state is a result of the quality and proportions of the aggregates and the paste which is also an indication for the strength of the existing bond between the ingredients.

In a good concrete product, every aggregate particles are fully coated with cement paste and the space between aggregate particles is completely filled with paste. In any particular set of materials, the quality of cement concrete is highly influenced by the amount of water used compared to the amount of cement. Relatively high water contents dilute the cement paste of concrete. Though a highly reduced amount of water in concrete production has its own effect in hydration of cement and the economy, the following are the advantages of reducing water content (Steven, et al., 2011);

- Increased compressive and flexural strength of concrete
- Lesser permeability, thus lower absorption and increased water tightness
- Increased resistance to weathering effect
- Good bonding strength between concrete and reinforcement
- Minimize drying shrinkage and cracking
- Minimize volume change from wetting and drying

The less water used, the better the quality of the concrete provided the mixture can be consolidated properly. Smaller amounts of mixing water result in stiffer mixtures; but with vibration, stiffer mixtures can be easily placed (Steven, et al., 2011). For particular purposes, the common purpose of entraining air in concrete is to increase the workability and to improve the resistance of concrete to weathering. Mostly the air voids left in concrete due to air-entraining agents are discontinuous and very small size with an average diameter of less than 0.05mm. So that entrained air is not a significant problem as compared to the entrapped air, which forms continuous channels and increases the concrete's permeability (Orchard, 1973), as cited in (Abebe, 2005).

The solid portion of hardened concrete is assumed as a composition of the mineral aggregate and the hardened cement paste, though there are some un-hydrated cement and a new product formed by the combination of the remaining cement with some of the water. After some time, the amount of free water left depends upon the extent of the combination of cement and water, and upon possible loss of water (Orchard, 1973), as cited in (Abebe, 2005). The fine aggregate and coarse aggregates will be discussed in sections 2.3 and 2.4 of this chapter.

2.2.2. Properties concrete

2.2.2.1. Properties of fresh concrete

Fresh concrete is defined as concrete at the state when its components are totally mixed but its strength has not yet developed. This period is related to the cement hydration stages in which the product can be shaped into any desired shape. The properties of fresh concrete directly influence the handling, placing, and consolidation, as well as the properties of hardened concrete (Anteneh, 2017). The following are some properties of fresh concrete;

A. Workability

Workability can essentially be defined as the amount of mechanical work required for full compaction of concrete with no segregation occurs because the final concrete strength is largely influenced by the degree of compaction (Sidney, et al., 2003), as cited in (Anteneh, 2017). An escalation of air void due to inadequate compaction could highly decrease the strength of concrete. The common characteristics of workability are consistency and cohesiveness. Consistency is the characteristics of concrete to easily flow in a fresh state (Adam, 1985), as cited in (Anteneh, 2017). The following are the factors that affect the workability of concrete;

B. Setting of concrete

Setting of concrete id the progressive change from fresh state to a hardened state. It differs from hardening because of the development of useful and measurable strength. Setting proceeds hardening although both are controlled by the progress in the hydration of cement (Adam, 1985), as cited in (Anteneh, 2017).

C. Hydration

The hydration of cement is not a temporary action but a progressive process for a long time, though the rate of hydration is fast in the beginning and continues over a very long time at a decreasing rate. Since concrete is cast in an open atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for progressive hydration to take place particularly in the top layer. Even in higher water/cement ratio used in concrete, extra water must be added to cover the loss of water because of absorption and evaporation. So that curing can be considered as the creation of a favorable environment during the early period for uninterrupted hydration (Anteneh, 2017).

2.2.2.2. Properties of hardened concrete

The major properties of concrete in a hardened state are strength, durability, shrinkage, creep and modulus of elasticity (Anteneh, 2017).

A. Strength of concrete

The compressive strength of concrete is commonly considered its most valuable property, although other characteristics such as durability and impermeability in fact important.

Compressive strength usually gives an overall picture of the quality of concrete because the need in strength of concrete is directly related to compression resistance of the structure of the hardened cement paste (Adam, 1985), as cited in (Anteneh, 2017). The 3rd, 7th and 28th-day compressive strength of concrete can be determined by a standard uniaxial compression test which is universally accepted as a general index of concrete strength. Moreover, other strengths like flexural and tensile can be correlated to this property (Anteneh, 2017).

In constant water-cement ratio and degree of compaction, it is acceptable that the compressive strength of concrete decreases with an increase in the specific surface of the aggregate. In addition, the presence of a higher amount of fine can increase the required amount of water and leads to a weak product. According to the test results of the Portland Cement Association, the 28th-day compressive strength increases as the fineness of aggregate while the workability limit is not exceeded (Denamo, 2005). As shown in Figure 2.2, compressive strength decreases with the increase in the aggregate to cement ratio by weight.

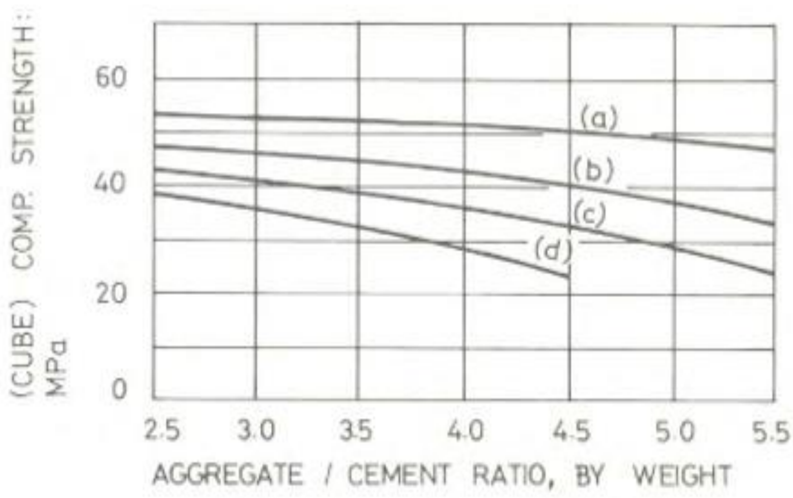


Figure 2.2 the effect of aggregate/cement ratio on strength of concrete (Denamo, 2005)

B. Durability

The durability of concrete is an ability of hardened concrete to resist weathering actions, chemical attack, and abrasion while maintaining its desired engineering properties. Concrete structures need different degrees of durability depending on the effect of the environment and the required purpose. The ultimate durability can be affected by concrete constituents, proportioning of those ingredients, interactions between the ingredients, and placing and curing practices (Steven, et al., 2011).

C. Shrinkage of concrete

In a normal concrete, the cement paste considered as the weakest portion compared to aggregates but properties of aggregates affect the other characteristics of concrete both in the plastic and hardened state since it is the three-quarters of the concrete mass. In unsaturated air concrete loses internal water content by evaporation, this leads to a decrease in the volume of concrete starting from a plastic state and continues for several days and months after the concrete has hardened. This change in dimension is called plastic and drying shrinkage (Mikiyas, 1987), as cited in (Denamo, 2005).

Shrinkage of concrete can be affected by mineral composition, grading and mechanical properties of aggregates constitute. The mineral composition of aggregates is important under comparable conditions since minerals can change their properties in wetted and dried conditions. The nominal size and grading affect the shrinkage indirectly. A well-graded aggregates with a large maximum size have a lower void space and permit the use of a leaner mix. Further, a larger maximum size of aggregate has the advantage of lowering water content. In both cases, the shrinkage will be lowered (Mikiyas, 1987), as cited in (Denamo, 2005). As shown in Figure 2.3, concrete made with different mix proportions of aggregate types, quartz aggregates have the least shrinkage when compared to concrete made with other types of aggregates (Denamo, 2005).

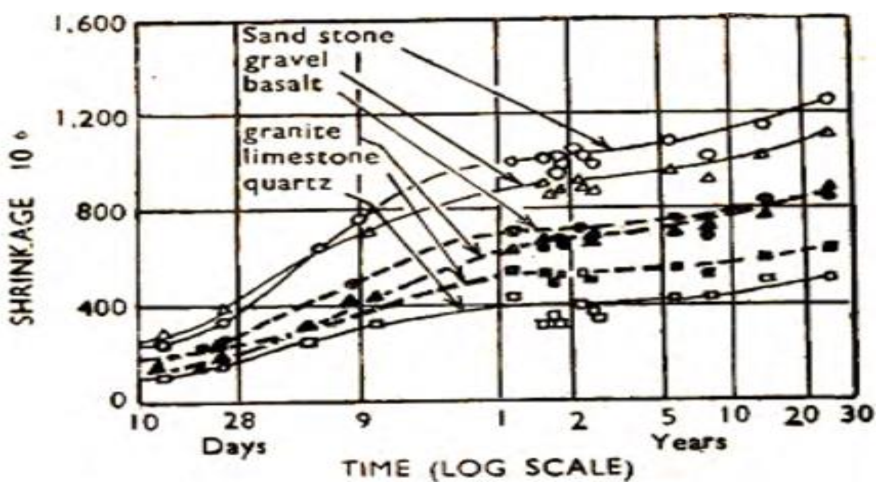


Figure 2.3 shrinkage of concrete (Shetty, 1982), as cited in (Denamo, 2005)

2.2.3. Quality of concrete

Concrete is a composite material by which the production process has its own effect, however, the quality and characteristics of ingredients are the baselines for the quality of the products. Good strength and poor strength products can be produced from exactly the same constituents by the difference in the quality control of the production process. Quality control in concrete production is a means of checking the quality of concrete constituents and production processes in compliance with the requirements stated in the acceptable code of practice. Mostly it is assumed to be done by the constructors who have the responsibility of providing a good quality of materials and workmanship as of agreed on the contract, though the quality control process needs the role of nearly all stakeholders in the projects and in the construction industry. In addition to the participation of almost all stakeholders, the quality control process needs the progressive inspection of the product by the responsible bodies; mostly the consultant (Abebe, 2005).

It is acceptable that quality has its own cost if the contractor is not responsible to control the quality in the construction state, there is the platform which makes the contractor pay the uncontrolled cost of quality in the defective period of the projects by the order of the quality assurer or the consultant. Many research findings state that constructions in Ethiopia is currently booming in various parts of the country, mainly in major cities and towns. Most of these construction projects are reinforced concrete structures in which concrete takes the major proportion in beams, columns, slabs and foundations, and other load-bearing elements. This indicates the quality of concrete is mandatory for the overall quality of the structures (Abebe, 2005). Generally, concrete is a none factory product that is produced in an open environment on-site in the presence of various factors that bring variations on concrete quality. Those factors are the quality of constituents, inconsistency concrete production processes and quality of workmanship and other environmental factors (Abebe, 2005).

2.3. Coarse aggregate

Aggregates mostly described as inert, granular, and inorganic materials that commonly consist of stone or stone-like solids. Aggregates can be used in road bases and various types of fill without the need of any binding materials, or can be used with binding materials including cement and asphalt to form composite materials or concrete. The most common purpose of aggregate is to form portland cement concrete. It is estimative that an ingredient occupying such a large fraction of the mass should have an important effect on the properties of both the fresh and hardened products (Abebe, 2005).

2.3.1. Physical properties of aggregates

Since at least 75% of the volume of concrete is occupied by an aggregate, the physical properties of the aggregates have a great impact on the strength, durability and structural performance of concrete. Therefore the aggregates should be well tested before any use of it to produce the right quality of concrete. The following are the essential properties of aggregate that can affect the performance of concrete (Anteneh, 2017).

2.3.1.1. Sampling of aggregates

In the production and consumption of aggregates evaluating all groups of the product is not feasible in terms of cost and time constraints. To make the quality checking process effective, samples shall be representative and certain precautions in sampling have to be made. The main aggregate sample to be tested shall be made up of the parts drawn from different parts of the whole product and the minimum number of this portion is described in BS 812, Part 105, 1990. Further in large samples, maintaining the representativeness by quartering or riffling reduction techniques is recommended (BS 812, Part 105, 1990; Adam, 1985), as cited in (Anteneh, 2017).

2.3.1.2. Particle shape and surface texture

The effect of particle shape and surface texture of an aggregate is more significant in the properties of fresh concrete than hardened concrete. It is usual that, rough, angular and elongated particles require more water to produce workable concrete than smooth, rounded and compact particles. So that aggregates particles that are angular consume more cement to preserve the same water to cement ratio. However, with good particle size distribution, both crushed and non-crushed aggregates (from the same rock type) give essentially the same strength for the same cement factor. In addition angular, elongated, flaky, and poorly graded aggregates decrease the property of concrete to be pumped (Steven, et al., 2011). A flat and elongated particle is a particle that has ratio length to thickness more than a specified value.

2.3.1.3. Grading coarse aggregates

The grading of aggregates controls the amount of cement paste required for a workable concrete since the void between aggregate particles is to be filled by the same amount of cement paste in a concrete mixture. Mostly the well-graded aggregate products which contain particles in all sieves are recommended for cost-effective concrete (Anteneh, 2017).

2.3.1.4. Soundness

The soundness of aggregate is the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These can be freezing and thawing, variation in temperature, alternate wetting, and drying in saltwater. Aggregates which does not resist the specified amount of volume change are unsound aggregates. The poor resistance to sulfate solution is a way of estimating soundness to weathering action, particularly where relevant service records are unavailable (Shetty, 1982), as cited in (Denamo, 2005).

2.3.2. Production of coarse aggregate

The quality of aggregates affects the strength, durability and structural performances of concrete elements. The natural aggregates are formed as a result of the processes of weathering and abrasion or through crushing a large parent rock mass. This shows that the properties of aggregates depend on the properties of the parent rock and the production process (Adam, 1985; Blackledge, 2002), as cited in (Admasu, 2015).

Most of the time production of coarse aggregates include blasting of rock, transporting of the crushed rock by conveyor to the crushing plant, and adjusting the crusher to give a range of different sizes by passing the crushed rock through a set of sieves. In order to produce a consistent concrete throughout different batching, the coarse aggregate shall be separated into several size fractions. The accumulations should be arranged in a horizontal manner with a gentle slope but not by end dumping method. The types of aggregates can be diverted by the difference in the geological locations of the parent rock. All rocks do not necessarily give similar aggregate qualities. The selection of a quarry site should be based on the availability and properties of the parent material, distance from the settlement areas, transport costs, the existing and planned land use, the quarry’s location and its impact on the environment. The selection of quarry sites for aggregates production should be decided after core samples are taken and tested for the suitability of the aggregates for the necessary physical and chemical properties (Denamo, 2005).

Excavating crushed stone, sand and gravel depend on the geological characteristics and the extent and thickness of the deposit. In the developed countries, open pit mining and quarrying methods are commonly used aggregate sources. Quarrying and mining stones from the parent rock requires drilling and blasting following extraction by using shovels, bulldozers, and draglines. Both sand and gravel deposits can be taken out with conventional earthmoving equipment such as bulldozers, front end loaders, and tractor scrapers. When the source is streams or water-filled pits, it can be excavated using draglines or from barges that use the hydraulic or ladder dredges. Further processing of excavated rock and large gravel requires crushing depend on the size of the final product. After crushing, the aggregate is moved by conveyors to be stockpiled by size and loaded on trucks, railcars, barges or freighters for the demanded areas (Wiliam, et al., 2005), as cited in (Admasu, 2015).

2.3.3. Aggregate selection

There are various types of aggregates based on different ways of classifications, however, aggregates shall select from the local and easily accessible quarry. The cost is substantially reduced, though the well-graded characteristics of aggregate has its own effect to minimize paste requirement. Many properties of aggregates depend mostly on the quality of parent rock, however, there are properties possessed by the aggregates which are critical as concrete production is concerned. Further, the selection of aggregates is needed to be exercised critically taking the economic factor into consideration (Blackledge, 2002), as cited in (Denamo, 2005).

The delivered aggregates directly to the mixing plant may not be economical, it can consume more cement content that of another source. In some cases, the additional cost of processing can be more than the reduction in cement costs of the concrete. Generally, the aggregate that brings about the required quality in the concrete with a minimum possible overall cost shall be selected. In the estimation of ingredient batch quantities for making mix adjustments, for computing effective water-cement ratios and for making estimates of quantities required for jobs, the physical properties of aggregate are needed (Troxel, et al., 1956; Shetty, 1982), as cited (Denamo, 2005). Methods that have been used or are used to choose the relative proportions of the various sizes are as follows:

- Trial mix of the concrete to obtain maximum economy with good workability
- Empirical criteria based upon
    - Unit weight or void content
    - Sieve analysis and grading diagrams

- Trial mixtures of dry aggregates to obtain maximum density
- Rule of thumb ratios

The trial mix of concrete is probably the most satisfactory since the final criterion of optimum proportions in concrete which most nearly possesses the necessary economy and workability, though it is time-consuming. Familiarity with unit weights and gradations is more advantageous as used as an excellent guide to the most desirable combinations. The third method can also be used as a guide but it has been pointed out, the maximum density of dry aggregates doesn't give optimum workability in a mixture, for this reason, either trial mixes or empirical modification will be necessary. Since there is no easy and acceptable mix design procedure except that of EBCS, the concrete producers obliged to use the procedures commonly ACI and DOE, which are developed for other countries (Denamo, 2005).

2.4. Fine aggregate

As most scholars define sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is characterized by size which is being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil type containing more than 80% sand-sized particles by mass. The composition of sand varies depending on the local rock sources and conditions, but the most consistent of sand is silica (silicon oxide) and calcium carbonate (ACI, 2003).

Sand has been used widely in the construction industry for many hundreds of years. Even during Roman times, it was widely used in the production of different tiles and cooking materials (The sand museum, 2019). General, sand can be used as a cheap filler for the cementing materials and to reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste of different products.

2.4.1. Types of fine aggregate

2.4.1.1. Natural sand

As many scholars agreed that, sand and gravels are widely distributed and abundant near existing and past rivers and streams, in alluvial basins, and in previously glaciated areas. Even though it is widely distributed, these aggregates are not universally available for use.

Where the locality lacks the aggregate source, the costly alternatives of importing aggregates from outside the area or substituting another material for aggregate are considered. Now a day natural fine aggregates which are available today, is deficient in many aspects for direct use for concrete production (Mikiyas, 1987), as cited in (Anteneh, 2017). Some of the factors are:

- It doesn't contain fine particles, in the required proportion
- Contains an organic and soluble compound that affects the setting time and properties of cement
- The presence of impurities such as clay, dust and silt coatings, increase water requirement and impair bond between cement paste and aggregate.
- The presence of organic materials affects the durability of the concrete, therefore, it shortens the life of the concrete product.

Though there is a limitation on the natural sand characteristic, the construction industry still rests on these sand sources because of its lower cost and no need for technology for production. Basically, the source of natural fine aggregates is three types (Sereneinteriors, 2019; Materialtree, 2019).

A. Pit sand (coarser sand)

It is a source for different types of sand that can be obtained from deep pits of abundant supply. It has a property of being grained which is sharp, angular and free from salts. It mostly has a reddish yellow color and mostly employed in concreting (Sereneinteriors, 2019; Materialtree, 2019).

B. Marine sand

This type of sand is taken from seashores. It has fine rounded grains and it is light brown in color. Sea sand is avoided for the purpose of constructing concrete structures since it contains salt and tends to absorb moisture from the atmosphere and brings dampness (Sereneinteriors, 2019; Materialtree, 2019).

C. River sand

Natural rivers sand occurs granular material composed of finely divided rock and mineral particles obtained near and beds of rivers. The composition of these types of sand is highly variable, depending on the local rock source types and conditions. River sand has the properties being fine and consists of fine rounded grains with almost white and grayish color. The most common constituent of sand in inland continental settings and nontropical coastal settings is silica (silicon dioxide), usually in the form of quartz. River sand is usually available in clean condition and issued for concreting and plastering (Sereneinteriors, 2019; Materialtree, 2019). The construction industry of Ethiopia mainly uses sand from streambeds, which are commonly formed from quartz-feldspathic basement rock, sandy marine sediments and alluvial deposits (Abebe, 2005; Denamo, 2005).

2.4.1.2. Manufactured sand

Crushed sand is used for aggregate materials having dimensions less than 5.0mm that is produced from crushed rock or gravel and intended for construction use. In modern technology, natural aggregates have proved to be significantly economical in use, for which reason extensive use of crushed sand has been concentrated on projects where the natural sand is not available. Since the crushing process has a good effect, manufactured sand has an irregular particle shape, rough surface texture and the particle size distribution curve which can be adjusted in the production stage of the material. The fineness of the particles and irregular shapes of the aggregates have bad effects on the workability and finish of the concrete produced using the crushed sand, as a result, manufactured sand has poor status in the construction industry (Shewaferaw, 2006).

In addition to commonly known crushed sand types, bone powder has proven to be a good concrete material when mixed in the right proportion. The optimum quantity of bone ash for which crushing strength is maximum is 10%. The final setting time of bone powder is very high as a result the possibility of cracks on the application is eliminated. The strength of bone powder concrete can be improved by adding additives that contain aluminum silicate as binding agents (Okoye, et al., 2016).

2.4.2. Production of fine aggregates

Production of concrete with regular quality requires a consistent source with acceptable properties of fine aggregate. For instance, sand supplied from beaches is generally unsuitable for good quality concrete since they are likely to have a high concentration of chloride because of the accumulation of salt crystals above the high tide mark. They are also considered as a single sized, which can make the batching of ingredients for mix design very difficult (Denamo, 2005). The moisture content of sand in the time of consumption for concrete should be kept within a practical range of stability. Storage of sand in a suitable and protected place is useful in reducing adjustments through variations in moisture content (Ethiopian Standard, 2005; Admasu, 2015).

Sand has a critical role as a concrete aggregate and it needs special attention when considering the means of process control. In coarse aggregates, various types of crushers can be used to upgrade mineral quality, while sand basically relies on the same techniques called particle exclusion that can be used to address both mineral quality and sizing. The change in a single size for quality reasons observably will affect sizing (Denamo, 2005).

2.4.2.1. Traditional sand production

In Ethiopia, the construction industry is developing from time to time. As a result, the demand for construction materials increases in all parts of the country. In Ethiopia, the production of sand from rivers is mainly done by the local grouped peoples with no standardized machinery and in a very primitive way, while in developed countries there is an organized way of production which is done by using different techniques. Sand production becomes one of the major activities that need the attention of the regulatory administration in a bid to meet the demands of the consumers. Though there are a lot of river quarries for the production of sand, the quality and the production process are very ignorable, as shown in Figure 2.4 (Biruk, 2014).

Figure 2.4 traditional ways of sand production in Ethiopia (Biruk, 2014)

2.4.2.2. Sand and gravel processing

Deposits of sand and gravel can commonly found in near-surface alluvial deposits and in subterranean and subaqueous beds. As many scholars state that sand and gravel are siliceous and calcareous products of the weathering of rocks and unconsolidated or poorly consolidated materials. The quality of produced sand and gravel is dependent on the production process, though the nature of sand is the main character of quality (USEPA, 2019). The commonly used sand and gravel processing include the following activities;

i. Exploration

The success of the mining project depends mainly on the extent of knowledge and value of the mineral ore deposit. Precise information about the location, characteristics, and value of the mineral ore deposit is collected during the exploration phase. This includes surveys, field studies, and drilling sample boreholes and other excavations (Yasmin, 2014; USEPA, 2019). The exploration phase may include clearing of wide areas of the tree to allow the entry of heavy vehicles mounted with drilling rigs. Many countries require a separate sensitive area or are near previously isolated communities. The mining project which involves the construction of any access roads should include exhaustive assessment of the environmental and social impacts of these roads. In the sand mining project, the exploratory phase should contain the assessment of the flow of water and the effect of mining on the lifestyle of the local community (Yasmin, 2014; USEPA, 2019).

ii. Mining

After construction of access roads and preparation of staging areas, mining may proceed in a moist or wet condition by open pit excavation or by dredging. All types of active mining have a practice of the extraction and concentration of minerals from the earth. In most cases, the proposed mining projects differ considerably in the planned method for extracting and concentrating the ore. After mining, the materials are transported to the processing plant by suction pump, earth mover, barge, truck, belt conveyors, or other means as shown in Figure 2.5 below (USEPA, 2019) as cited in (Yasmin, 2014).

iii. Sand and gravel processing

The processing of sand and gravel for a specific market can be done by using different combinations of washers, screens, and classifiers to segregate particle sizes; crushers to reduce oversized material; and storage and loading facilities. After excavation, wet sand and gravel raw feed is stockpiled or emptied into a hopper, which typically is covered with a "grizzly" of parallel bars to screen out large-sized stones. From the hopper, the material is transported to fixed or vibrating scalping screens by different mechanisms, like gravity, belt conveyors, hydraulic pump, or bucket elevators (Yasmin, 2014; USEPA, 2019). Oversize material may be used for erosion control, reclamation, or other uses, or it may be directed to a crusher for size reduction and reused for crushed sand or crushed aggregate. After one or two-stage crushing, the material is returned to the screening operation for sizing (USEPA, 2019).

As shown in Figure 2.5, screening is used to separate the sand and gravel into different size ranges. The screened and sized gravel is transported to stockpiles, storage bins, or, in some cases, to crushers by belt conveyors, bucket elevators, or screw conveyors and the sand is freed from clay and organic impurities by log washers or rotary scrubbers. Following the scrubbing process, the sand typically is sized by water classification, while wet and dry screening is rarely used to size the sand. After the classification process has finished, the sand is dewatered using screws, separatory cones, or hydro separator and then the sand is transported to storage bins or stockpiles by belt conveyors, bucket elevators, or screw conveyors (Denamo, 2005; Yasmin, 2014; USEPA, 2019).

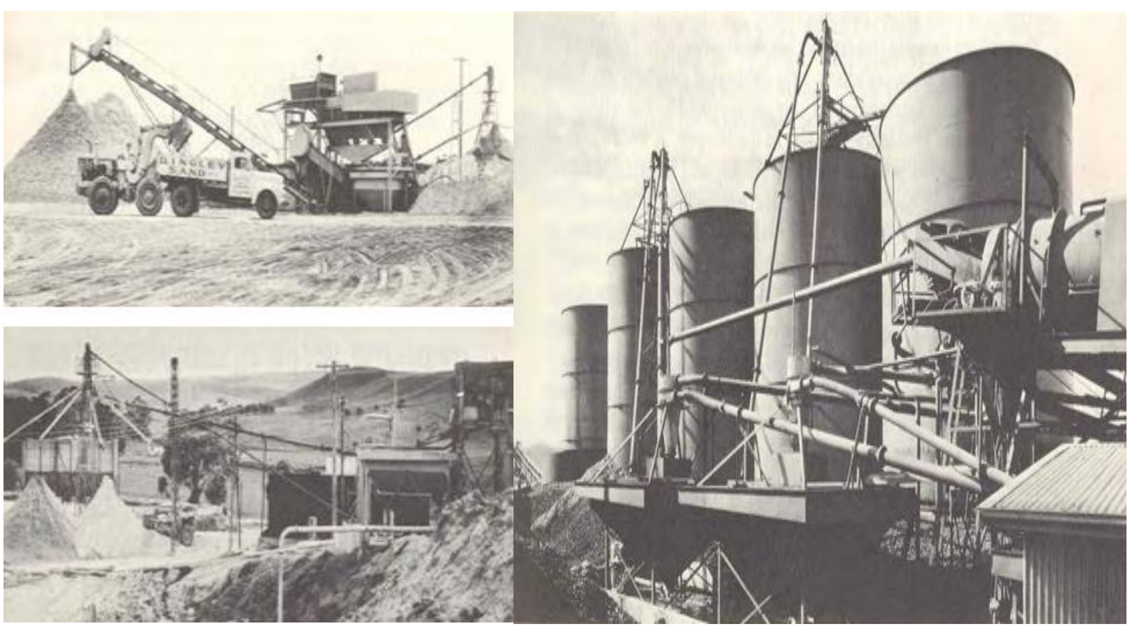


Figure 2.5 modern sand processing (Taylor, 1977), as cited in (Denamo, 2005)

2.4.3. Requirement of sand for concrete

Aggregate has a technical advantage on concrete by providing higher volume stability better than the cement paste alone. Though there are aggregate products that include both fine and coarse aggregates called all in one aggregate, to make sure that there is a reasonable amount of sand, the separate delivery, storage and batching of coarse and fine aggregate is essential. Concrete requires a consistent source, character, grading and moisture content of fine aggregate to be a uniform product. For this reason, before using aggregate as concrete making material, it is important to examine whether those aggregates are fit for the intended purpose and tests on-site and laboratory should have to be made. In the construction industry, there are different standards which regulate the minimum and maximum requirement with related to construction activities and materials. So that, the suitable properties have been recommended by different bodies in order to obtain the preferred quality of concrete (Taylor, 1977; Blackledge, 2002), as cited in (Denamo, 2005). The requirements of sand as recommended by different scholars and regulatory standards have discussed below;

A. Grading of fine aggregate

The particle size distribution of fine aggregate mostly depends on the type of construction, the richest of the ingredients mixture and the nominal maximum size of coarse aggregate. In a case of that water to cement ratio is kept constant and the ratio of fine to coarse aggregate is chosen properly, a wide range in distribution can be used without measurable effect on the strength of concrete.

Table 2.1 fine aggregate grading limit as recommended by ASTM C 33 and AASHTO M 6

Sieve size	Recommended percentage passing by mass
9.5 mm (3⁄8 in.)	100
4.75 mm (no. 4)	95 to 100
2.36 mm (no. 8)	80 to 100
1.18 mm (no. 16)	50 to 85
600 µm (no. 30)	25 to 60
300 µm (no. 50)	5 to 30 (AASHTO 10 to 30)
150 µm (no. 100)	0 to 10 (AASHTO 2 to 10)

However, strength, best economy, and durability will sometime be achieved by adjusting the concrete mixture to suit the distribution of locally available aggregates (Steven, et al., 2011). In general, the fine aggregate particle size distribution, which is recommended by (ASTM C 33, 2007; ASTM C 136, 2006) is mostly considered normal for most concrete structures. In addition to the standard percentage pass, (ASTM C 33, 2007) recommends the following requirements to be considered in the grading of fine aggregates.

- Particle weight retained between two consecutive standard sieves should not be more than 45%.
- The fineness modulus must be between 2.3 and 3.1 and also should be uniform with no more than 0.2 difference from the typical value of the aggregate source. If this value is not attained the fine aggregate should not be allowed for use, except suitable adjustments are done in proportioning of fine and coarse aggregates.
- The amount of sand which passes through the 300 µm (no. 50) and 150 µm (no. 100) sieves affect workability, surface characteristics, air content, mix water and bleeding of concrete. In many specifications allowable passing through 300 µm (no. 50) sieve is 5% to 30%.

The lower limit may be sufficient for relaxed concrete placing conditions and where concrete is mechanically finished. However, for concrete floors to be finished by hand and where a smooth surface texture is wanted, fine aggregate with more than 15% of pass in 300 µm (no. 50) sieve and more than 3% pass in 150 µm sieve should be used (ASTM C 136, 2006; Steven, et al., 2011). Fineness modulus of sand usually used as an index to the fineness or coarseness and uniformity of supplied materials though it cannot be the indication of grading. According to (Denamo, 2005), the following limits can be taken as guidance.

- Fine sand: FM of 2.2 - 2.6
- Medium sand: FM of 2.6 - 2.9
- Coarse sand: FM of 2.9 - 3.2

B. Organic impurities

The strength and wear-resistant properties of aggregates are obligatory in producing suitable materials for the construction industry, but these characteristics alone cannot be a guaranty for the quality of produced concrete and other materials. Aggregates should be free from organic impurities for the effective hydration process of cement. However, it is considered that organic impurities present in sand rather in coarse aggregate. According to (ASTM C 40, 2004), for construction purposes, fine aggregates should have a value of 1 to 3 in an indication of a color test for organic impurities. If the indicator shows 4 or 5 the sand shall be rejected unless it is treated to remove the impurities (Adam, et al., 2010).

C. Silt content

In consumption of sand silt and crushed dust may be present either as a surface coating or loose material mixed with sand particles. In both forms silt and clays should not allow being present in high quantities because of that it decreases the fineness modulus and increases the surface area, further this increases the amount of water needed to wet all the particles in the mix (Adam, et al., 2010). As recommended in the Ethiopian standard, the maximum allowable silt content of sand which is used in construction shall be 6%, so that the silt content above this value needs to be treated in order to remove the silt or clay (ES 1990) (Abebe, 2002).

D. Unit weight

The bulk density or unit weight of an aggregate is the mass or weight of an aggregate which has filled in a unit volume of a specified container. The volume considered in this measurement shall be that of occupied by both aggregates and the voids between aggregate particles (ASTM C 29/C 29M, 2007; ASTM C 1252, 2006). It is generally accepted that the unit weight of fine aggregate which is used in normal-weight concrete can be from about 1200kg/m^3 to 1750kg/m^3 (75 to 110 lb./ft3).

E. Porosity and absorption

The porosity, permeability, and absorption of an aggregate are the measures of internal void within individual aggregate particles. These properties affect the bond strength with the cement and, the resistance of concrete for freezing and thawing action, chemical resistance, abrasion resistance and other properties of concrete (ASTM C 128, 2007).

The pores of aggregates widely differ in size over an extensive range. In certain cases, the smallest pores are larger when compared to the gel pores in the cement paste. Some of the aggregate pores are obtained totally in the internal part of the aggregate particle, while others have an opening on the surface of the particle. In later cases, there is significant penetration of water through the pores, though, the amount and speed of penetration dependable on the size, connectivity and total volume of pores. Before using the aggregates in concrete production the absorption and surface moisture of aggregates should be determined so that the total water content of concrete can be estimated to correct the batch weights in a good manner. It is recommended by most scholars that the absorption capacity of sand should be less than 10%.

F. Specific gravity

As many intellectual defines, relative density of an aggregate is a ratio of its mass to the mass of an equal absolute volume of water (ASTM C 128, 2007). Mostly it is used in certain calculations in ingredient mixture proportioning and controlling, such as the number of aggregates in the absolute volume method of mix design. Though it is not an absolute measure of aggregate quality, some porous aggregates which have low specific gravity have faster freezing and thawing deterioration than aggregates with high specific gravity. Most natural aggregates have relative density within the range of 2.4 to 2,9 with corresponding particle (mass) densities of 2400kg/m^3 and 2900kg/m^3 (150 and 181 lb./ft3). As many material experts recommend the specific gravity of sand to be used in construction should be from 2.4 to 3.0.

G. Bulking of sand

The presence of moisture has a significant effect on the properties of construction materials. Specifically fine aggregates have small sizes to be easily separated from each other in a matrix of sand by the action of water. This results in the increase in the volume of fine aggregates which is bulking. It is an increase in the volume of a specified mass of fine aggregate produced by the films of water pushing the particle apart. However, the fine aggregate can be free from water effect previously, bulking can occur at the time of excavation, relocated or stored in damp condition. Bulking of sand does not affect the ratio of concrete materials by mass, but it results in a smaller mass of sand occupying the fixed volume of the measuring box when using volume batching. That is the reason for most professionals to consider volume batching as a deceptive practice. Most of the time the volume change of sand is dependent on the moisture content (Adam, et al., 2010).

2.5. Standardization of aggregates

Standardization is can be defined as a model or general acceptance by authority, consensus, or custom, created and used by various levels of interest. It is required not only to keep the procurement for the right quality of incoming material, but also for cost reduction. The main target of standardization is to have consistent standards for similar items, and the standard evolved should take cognizance of the indigenous availability of materials to the maximum extent possible. The industry has become increasingly interested in assessing its economic efficiency and more concerned in the role of standardization (Gopalakrishan, et al., 2003), as cited in (Denamo, 2005). The major benefits of standardization can be the following;

- Standardization helps reduce inventory items on site
- It helps in evolving better means of communication about the material being considered
- It forms a base for further inventory analysis
- The specification of items can be more clearly spelled out, making quality control firm

2.5.1. Aggregate beneficiation

As the main stages of aggregate production, aggregate processing consists of two steps. The first is basic processing, which includes crushing, screening and washing to obtain proper gradation and cleanliness as shown in Figure 2.6. The second is beneficiation which is upgrading the quality by processing methods such as heavy media separation, jigging, rising current classification and crushing. In heavy media separation, aggregates are passed through a heavy liquid comprised of finely ground heavy minerals and water proportioned to have a relative density less than that of the required aggregate particles but higher than that of the deleterious particles. The heavier particles settled to the bottom while the lighter particles float to the top surface of the mix. Jigging used for separating aggregate particles with small differences in density by pulsating water current. Upward pulsations of water through a jig box helps to move the lighter material into a layer on top of the heavier material and it later removed. Rising-current classification used to separate particles with large differences in density. Mostly less density wood and lignite are floated away in a rapidly upward-moving stream of water. Crushing has the purpose of removing the soft and friable particles from coarse aggregates. This process is sometimes the only means of making the material suitable for use, however, some acceptable material can be lost and removal of all harmful particles may be difficult and expensive. (Gopalakrishan, et al., 2003), as cited in (Denamo, 2005).

Figure 2.6 coarse aggregate production plant (Blue Nile -around Kaliti) (Admasu, 2015)

2.5.2. Handling of aggregates

Materials handling is not merely a site problem, the designer, the manufacturer, and the contractor contribute to its quality. As shown in Figure 2.7, poor handling of materials increases site costs. Construction materials can be readily available naturally or can be produced through a manufacturing process. It is usually easy to control the quality of construction materials that pass through a manufacturing process. Though it is very difficult to have a consistent quality construction material naturally and used directly for construction purposes.

Figure 2.7 handling of aggregates around the concrete batching plant (Admasu, 2015)

The convenient and cheapest way of construction materials to load and unload is near the production site and around the construction site to be used, respectively. The techniques of aggregate loading and unloading have implications for the handling of different types of aggregates since these materials are often loaded and transported in trucks with elevated sides. It is crucial to prepare clean, hard base and substantial partitions to separate the different aggregate sizes and to prevent spillage from one bay to another, otherwise, the bottom 300mm of the aggregate stockpile should not be used because of the chance of contamination by dirt and water. In the absence of good handling of aggregates at the production place, in storage places and at construction sites, the problem of segregation, degradation, and contamination can occur. (Blackledge, 2002), as cited in (Denamo, 2005).

A. Segregation

The production process of aggregates shall be acceptable in terms of protecting particle settlements because it is the way to produce quality products. It is the most critical time where inputs are properly measured, evaluated, controlled and conformed for the uniformity and suitability of products. However, it is not always possible that jobs are finished when uniform products appear on the last belt. In addition, the coarser particles are thrown away and the fine particles tend to drop down (Denamo, 2005).

B. Degradation

The breaking down of the product can occur when equipment or other loads are overrunning on top of stockpiled aggregates. Aggregate particles that are stockpiled for two or more years must be rechecked for gradation, shipping and contents and quality of minerals (Admasu, 2015).

C. Contamination

Contamination mostly caused by carelessness and poor housekeeping. The stockpiles of different products are dumped or stockpiled near each other so that they grow together. Machinery can track dirt or other foreign material on stockpile areas as it moves near and over it. The old piles are more subjected to wind-blown fines over time and the cleanness of this shall be checked before shipping. Figure 2.8 shows the correct and incorrect ways of aggregates handling (Denamo, 2005).

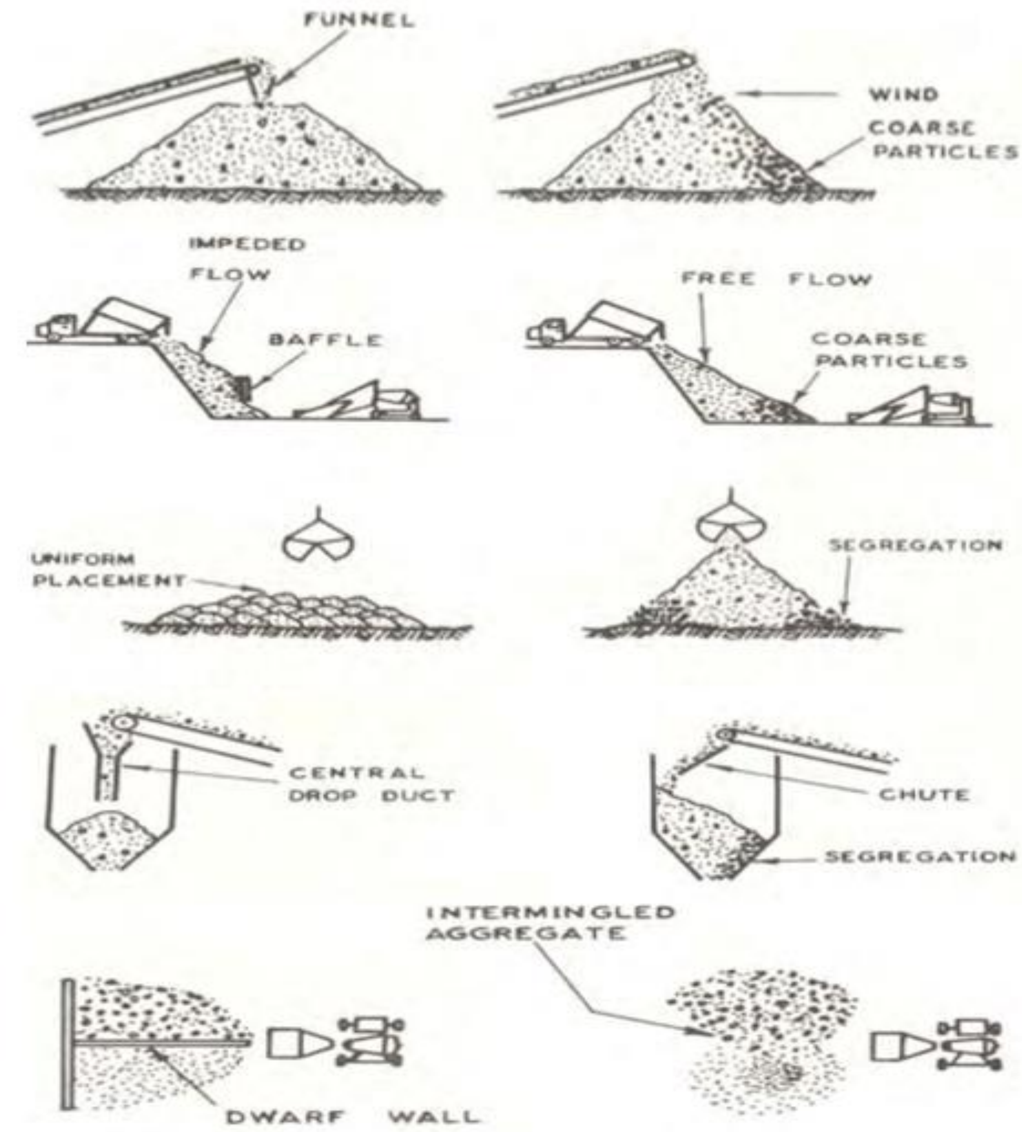


Figure 2.8 correct and incorrect (right and left respectively) handling methods (Mikiyas, 1987), as cited in (Denamo, 2005)

Stockpile arrangement is one of the strategies to control aggregate handling. Stockpiles must be pre-planned as short-term storage areas. Withdrawal of materials from stockpiles should be monitored so that it can be balanced regularly. There must be an easy system for withdrawing materials from the stockpile. Materials should be stacked so that access to other components is not obstructed. Mechanical equipment can be operated without additional manual assistance. The producer is assumed to describe the designation and standard operating procedures on building stockpiles for each product, and to educate all those involved in their responsibilities in the procedure (Denamo, 2005).

2.5.3. Construction materials management

Material management can be defined as planning organizing and controlling the material related activities in the construction site and challenging the material producers to supply standardized and consistent products. In the construction industry, it is difficult to perfectly manage and keep construction materials (especially bulk materials) safe except the product is standardized in the quarry level (Chitkara, 1998), as cited in (Denamo, 2005). According to (Khyomesh, et al., 2011), construction material management has the following objectives;

- Efficient materials planning
- Procuring and receiving
- Storing and inventory control
- Improved departmental efficiency
- Supply and distribution of materials
- Quality control and quality assurance
- Good supplier and customer relationship

2.5.3.1. Benefits of construction materials management

Many research finding shows that the major cause for the higher cost of construction projects is the cost of construction materials and wastages. As a result of the effective usage of materials, poor materials management in the project shall be avoided. Though the extent is dependent on the construction environments, the following are the main benefits of material management in construction projects;

A. Improved craft labor productivity

The advantages related to the productivity of labor on projects that use integrated materials management systems are believed due to two interdependent factors. The first is that materials are more likely available when needed, while the second is that, craft supervision can plan the job around material availability (Ballard, 1994), as cited in (Denamo, 2005).

B. Reduced bulk materials surplus

An excess amount of construction materials is most probably to occur on projects in which the take-off function is being performed before final revised design drawings are available. The factors that affect the potential materials surplus are the timing of the initial orders and the volume of materials actually purchased in the early purchases (Ballard, 1994), as cited in (Denamo, 2005).

C. Reduced materials management manpower

In the presence of effective materials management system, experienced materials professionals will be allocated to accomplish the field control and warehousing functions that are traditionally done by craft personnel. The advantage of allocating professionals in a task that can be performed by craft personnel is to reduce field manpower requirements (Ballard, 1994), as cited in (Denamo, 2005).

2.6. Aggregate production and the environment

The aggregate production has faced many challenges a growing, public awareness in relation to the environmental profile of its activities. According to (Denamo, 2005), the important areas of concern are:

- The non-renewable character of the natural resources, especially in regions facing a coming shortage of adequate local materials
- The environmental impact on the neighborhood and of the quarrying and of the materials transport related to the quarrying activities
- Land-use conflicts between quarrying and e.g. Agriculture, recreation, building sites, archaeology - especially in densely populated regions
- A lack of sustainability in production, characterized by inferior mass balance (i.e. High percentages of e.g. Surplus fines to be deposited) and high energy consumption needed per. Ton aggregate produced.

These issues concern the relation between the aggregate production industry and its surrounding society will be determinant for the survival of production industry potentials. In the future, only companies who can accomplish the environmental parameters in their planning and execution of own activities can get public acceptance and can able to survive. However it is very difficult to merge the environmental issues to the industry; for instance creating environmentally-friendly and economically profitable industrial plants that integrate quarrying and industrial production, including the plans for restoration and area use after the quarrying period is completed is not an easy job (Denamo, 2005).

2.6.1. The impact of aggregate production

2.6.1.1. Biological/ecological impacts

In the quarrying process, removal of channel substrate, resuspension of streambed sediment, clearance of vegetation and stockpiling on the streambed are commonly practiced. These activities have an obvious effect on the existence of riparian habitats and species. Many studies show that many hectares of fertile streamside land, valuable timber resources and wildlife habitats in the riparian areas have lost annually due to sand extraction. Degraded stream habitats result in loss of fisheries productivity, biodiversity, and recreational potential. Severely degraded channels may decrease the level of land and aesthetic values (Yasmin, 2014; Semere, 2013).

2.6.1.2. Cascading impacts

In most cases cascading impacts are started by the removal of rock in engineering activities, which change the natural system. For instant aggregate mining in some regions might lower the groundwater table, which will remove the buoyant support of rock that overlies water-filled caverns, which might result in a land collapse and create a sinkhole. Sometimes these impacts can have a severe effect on the areas above the limits of the aggregate operation. In addition, quarrying has a dramatic visual impact, though the extent of impact is the function of the size of the quarry, the number of quarries, and the location of the quarry with respect to the overall local landscape and landforms. Figure 2.9 shows the size of quarries increased over time, and so has their own impact (Smart, et al., 1991), as cited in (Semere, 2013).

Figure 2.9 quarries occupying a significant part of the visual landscape (Smart, et al., 1991), as cited in (Semere, 2013)

2.6.1.3. Engineering impacts

The commonly known engineering effects of quarrying is a change in geomorphology and change in land use with the associated change in the visual scene. The most common engineering impacts can be accompanied by loss of habitat, noise, dust, vibrations, chemical spills, erosion, sedimentation, and dereliction of the mined site, though most engineering impacts can be controlled, mitigated, kept at tolerable levels, and restricted to the immediate vicinity of aggregate operation by applying responsible operational practices (Baksdale, 1971; Smart, et al., 1991), as cited in (Semere, 2013).

A. Blasting

The public compliment for the quarrying which practice crushing near population centers is about blasting noise. Blasting may occur daily in some time intervals, however, the techniques used in crushed stone operations are significantly different from those used in dimension stone quarrying. As shown in Figure 2.10, when a blast is exploded, some energy will escape into the atmosphere causing a disturbance in the air. The part of this disturbance is sub-audible (air concussion) and part can be heard (noise). The noise in blasting operation expected to increases with the amount of explosive, with specific atmospheric conditions, and with proximity to a blast though people respond differently for blasting. In order to mitigate the direct impacts from ground shaking and air concussion, blasting should be practiced by following widely recognized and well-documented limits (Semere, 2013).

Figure 2.10 rock drilled and blasted as crushed stone (Langer, et al., 2001), as cited in (Semere, 2013)

B. Noise

Noise can be produced by from earth moving equipment, processing equipment and blasting in the production of aggregate and dimension stones. The extent of noise effects are highly dependent on the sound source, the topography, land use, ground cover of the surrounding site, and climatic conditions. In any situation, the aggregate quarries are responsible for assuring that the noise released from quarrying does not exceed levels set by regulations (Langer, et al., 2001), as cited in (Semere, 2013). Figure 2.11 shows the noisy equipment enclosed by sound-deadening structures.

Figure 2.11 noisy equipment enclosed in sound-deadening structures (Langer, et al., 2001), as cited in (Semere, 2013)

C. Dust

In quarrying process dust can be occurred as fugitive dust from excavation, from haul roads, from blasting, or can be from a single source, such as drilling, crushing and screening. The characteristics of quarry that affect the impact of dust released during the extraction of aggregate and dimension stone include rock properties, moisture, ambient air quality, air currents, the size of the operation, proximity to population centers, and other sources of dust. Mostly dust concentrations, deposition rates, and potential impacts tend to decrease rapidly away from the source because of gravity (Langer, et al., 2001), as cited in (Semere, 2013).

2.6.1.4. Socio-economic impact

As the biggest mineral deposit on earth, sand and coarse aggregate production have an economical benefit despite the environmental impact that has its own impacts. In the developed countries the sand and gravel production has a significant effect on the nation's economy, however, the production is undergone in an equipment based manner. Further, the industry has a great effect on decreasing unemployment in the countries (Yasmin, 2014; Yayesh, 2017).

2.6.1.5. Geological/physical impact

In the aggregate extraction process, the sediment topography and type will be changed through the deduction of material and resettlement of fine particles (Yasmin, 2014). The following are the common physical effects of aggregate production;

A. Stability of structures

Many research finding states that sand production causes turbulence of basin movements and removal, it further leads to instability of banks (Yasmin, 2014). The loss of bank stability can cause the following issues;

- The undercutting and collapse of river banks
- The loss of adjacent land and structures
- Upstream erosion caused by an increase in slope and changes in flow velocity
- Downstream erosion caused by increased carrying capacity of the stream, downstream changes in patterns of deposition, and changes in channel bed and habitat type.

B. Groundwater

Sand along riparian areas can be used as a spongy layer and help in recharge of groundwater through the percolation of water through different layers of sand. In the disturbance of these spongy layers by quarrying, the recharge of groundwater is affected. In addition, river sand mining changes riverbeds into large and deep pits which are unsuitable for further extraction and local landscapes (Yasmin, 2014).

C. Water quality

Due to the floating of dust particles due to storing and dumping of excess mining materials, organic matters, oil spills or leakage from excavation machinery and transportation vehicles, the irregular river characteristics are common. Further, this affects the water quality of the river both at the quarrying site and in the downstream. The presence of suspended solids can expressively increase the cost of water treatment (Yasmin, 2014).

2.6.2. Controlling aggregate production

Dust and noise can be minimized and the severe effect can be avoided, though they are the part of aggregate mining. In addition, the site appearance of the sand and gravel operating place is an important concern to surrounding residents. The more visible a mining operation shall be to the public, while less compatible part of mining operation shall be located in the adjacent land uses since the aesthetic itself can create a positive impression. The application of a cautious operational plan will keep dust and noise within acceptable limits recommended by regulatory bodies (Langer, et al., 2001), as cited in (Semere, 2013). For the wellbeing of the public and the environment, reclamation and conservation techniques should be planned and practiced in the opening, operating and closing of sand and aggregate quarrying. These include sloping, seeding, noise and dust control mechanisms, and erosion and sediment control systems (Semere, 2013; Cynthia, 2003).

A. Dust control

The impacts of operation generated dust commonly can be moderated through the process of design, engineering, and use of dry dust collection or wet suppression systems. As shown in Figure 2.12, monitoring fugitive emissions in operations can depend on good housekeeping practices (Cynthia, 2003), as cited in (Semere, 2013).

Figure 2.12 water trucks minimize dust in and around quarry (Langer, et al., 2001), as cited in (Semere, 2013)

The recommended measures minimize the dust are;

- Careful location of process equipment and stockpiles
- Dust collection on drill rigs and stationary process equipment
- Reducing the drop height of dusty material
- Water or chemical applications on haul roads and rubble piles
- Control of vehicle speeds and
- Construction of windbreaks, buffer zones, and plantings.

B. Noise control

Mostly noise travels faster in dense and cold air than in warm air, and when there are inversions in the atmosphere. The recommended techniques which can be used in controlling noise are; use of mufflers and backup alarms that adjust their volume relative to ambient noise levels, selecting low noise plant equipment and the use of flexible equipment mounting systems to limit the noise from mobile equipment. On-site techniques including protection equipment, landscaping, berms, and stockpiles also can be constructed to form sound barriers, though locating noisy equipment (such as crushers) in a sound deadening enclosures away from populated areas is recommended (Cynthia, 2003; Langer, et al., 2001), as cited in (Semere, 2013).

C. Erosion and sediment control

In some sand and gravel mining operations, erosion and sediment deposition are concerns, though erosion proceeds at a slow rate. In the absence of protective vegetative cover and the underlying soil has exposed, the rate can be greatly accelerated. As a result exposed land can experience erosion rate to 1,000 times the rate of undisturbed land. Sedimentation and erosion effect can be minimized by the application of mine planning and the use of erosion control measures. Further erosion control plans can be organized for land disturbance effects (Cynthia, 2003; Semere, 2013).

D. Protecting the environment

An aggregate operation is temporary land use so that at the end of the production process the land should be converted into another beneficial use. Modern technology and scientific investigation methods allow aggregate operations with no effect on the sustainability of the environment, which excellently control physical disturbance, protect ground and surface waters, use safe blasting procedures, and have long term operation and closure plans that consider the habitat and community needs. It plays a great role in the reduction of environmental impacts to manageable and acceptable levels (Cynthia, 2003; Semere, 2013).

E. Managing physical disturbance

Planning of an aggregate operation is accompanied by a change to the landscape as observed from either the site or locations that surround it. The characteristics of this change depends on the surface forms, slopes, natural ground cover, the type of operation (Cynthia, 2003; Semere, 2013). As shown in Figure 2.13, super-quarry will has great importance in avoiding fragmented effects.

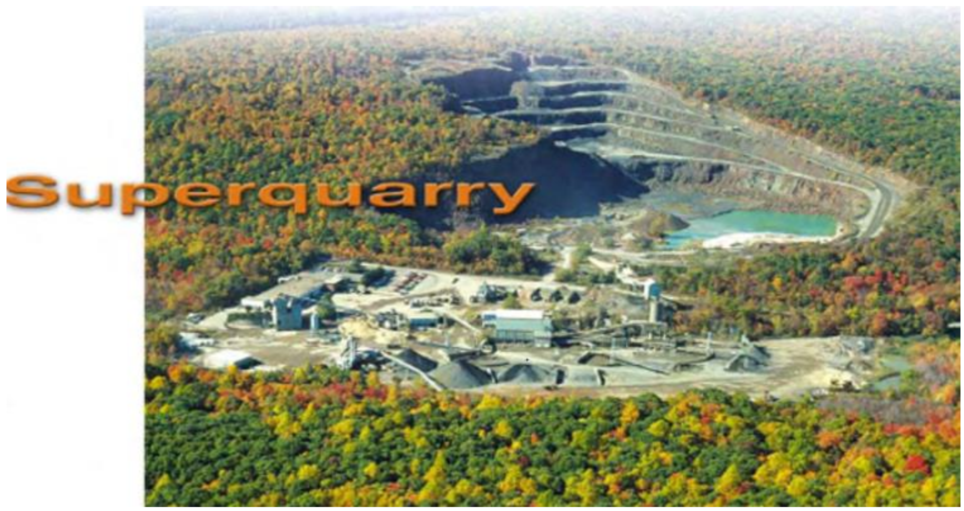


Figure 2.13 a super quarry (Kestner, 1994), as cited in (Semere, 2013)

Though the removal of these change is not possible with the need of the final products, unsightly changes can be reduced to acceptable condition by the following activities;

- Proper landscape analysis, design, and operations;
- Extracting aggregate from the most suitable deposits; and
- Creation of super quarries and the use of underground mines, depending on the situation.

In order to achieve the regional demands of aggregate, creating a single large operation (super quarry) at an environmentally acceptable site may be preferable to many smaller operations at scattered locations (Kestner, 1994), as cited in (Semere, 2013).

2.7. Knowledge gap from the literature

Based on the addressed works in the above topics, most research assumes the quality of sand has checked by considering the properties of sand as a natural characteristic of the materials, though there is the impact of external factors on the property of sand from the rivers. Most researchers focus on the effect of sand production on the environmental ecology, local and global economy of the state, different existing structures and other public properties in the area. It indicates a one way understanding of the perceptions that sand production system affects the environment and the wellbeing of community's lifestyle, but in developing countries like Ethiopia the environ and the societal activities has its own effect on the production process and further on quality of produced sand because of the lower attentions given for processing and standardization.

The research done on the quality of river sands around Woldia town indicates that the physical properties of sand were good but there was a number of external factors by which the sand quality has fluctuated and the sand suppliers have not able to control those effects (Belete, et al., 2017). Though there are many environmental and societal factors that likely affect the production process and the quality of river sand, the researcher assumes that the quality of sand from the rivers can be affected mainly by the following practices.

- Human, animals, and truck action
- Detergents and sewage from the towns
- Soil, leaves, and flora in the river area
- Water flow of the river
- Sand production, treatment and storage systems

In the actual sand production environment, it is difficult to measure the exact effect of a single factor since the factors are uncontrolled and cannot exist in a single exact form. The preparation of samples should be done carefully for each case of experiments to make it free from the interference of factors other than the considered one. The effect of a single factor can be estimated by measuring the difference in specific characteristics of sand for the presence and extent of effect by the considered activities.

3. Materials and methods

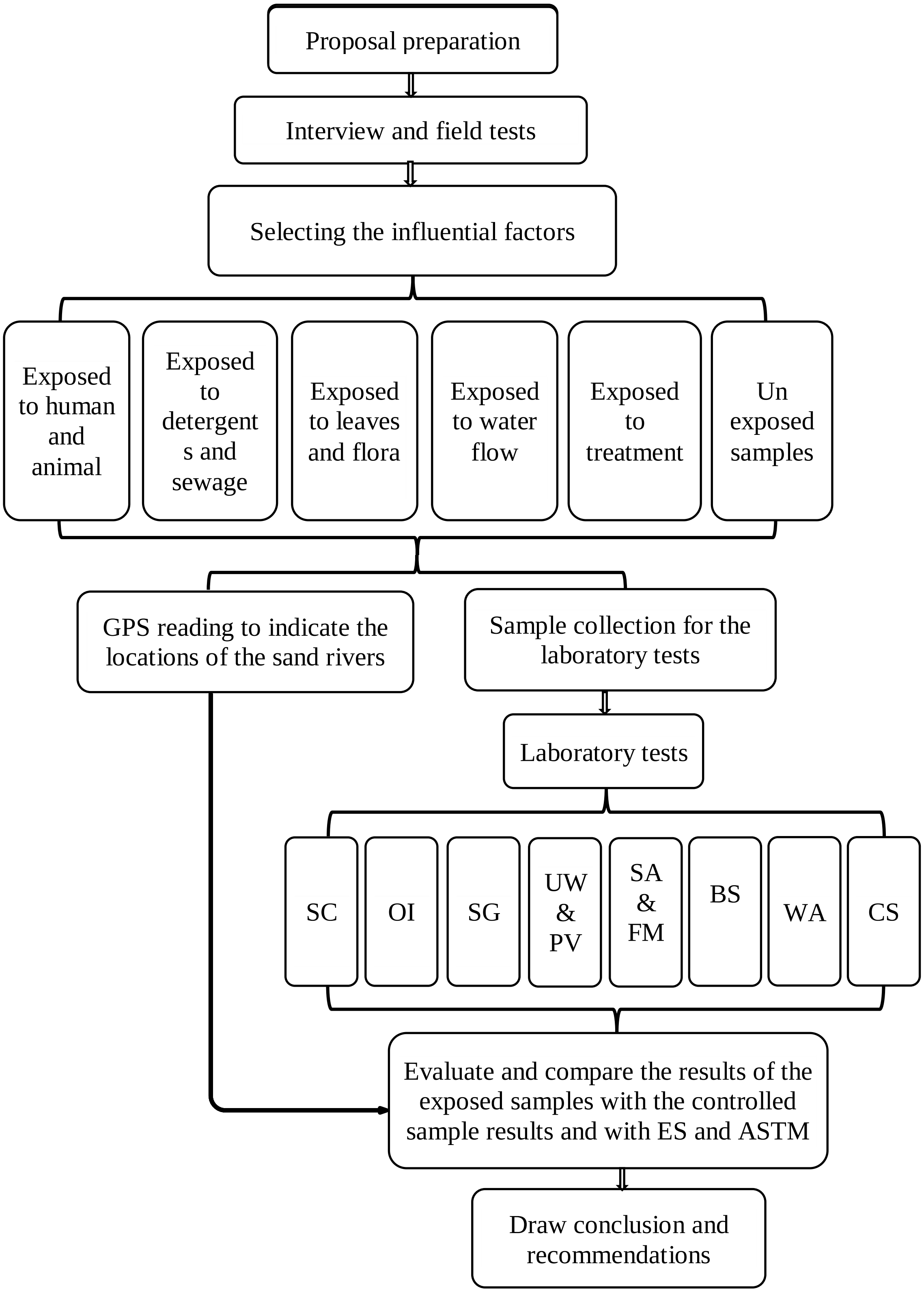
3.1. Study area description

This study has focused on the outskirts of Woldia town which is the capital of the North Wollo zone in the Amhara region, Ethiopia. North Wollo zone is located in the northeast of Addis Ababa, the capital of Ethiopia. It is surrounded by south Wollo, south Gondar, wag Hemra, Tigray region, and afar region in south, west, north, northeast and east directions respectively. It has a mountainous and steep slopes landscape while the highest point is mount Abune Yosef. Lalibela is a well-known town in the area for its rock-cut monolithic church which has registered in UNESCO since 1978, while the capital of this zone is Woldia town which is a hillside market town with a latitude of 11, 8333, longitude of 39.6833 and an altitude of 2112m above sea level. Woldia town is located at a distance of 510km from Addis Ababa and 360km from Bahrdar which is the capital of the Amhara region.

In the north Wollo zone, there is the small number of river sand quarry sites used for the majority of projects constructed in the specified area and some other towns of the region. This study concerns the quality of sand for the five sand quarry sites; Alawuha River, Golina River, Hormat River, Mersa River, and Tikurwuha River. Alawuha, Golina and Hormat rivers located in Raya Kobo woreda at a distance of 11km, 38km, and 47km respectively from Woldia. Mersa River is located in Mersa town 30km from Woldia, while Tikurwuha River is located in a 5km distance near Woldia town. River quarry sites were the nearest and the most commonly used site in the consumption of construction projects in the area. The satellite views of the study area river locations are shown by the red pots in Figure 3.1.

Figure 3.1, satellite view of the study area (source: www.latitude.to, Nov 2018)

3.2. Research design



Graph 3.1 research design and data collection procedures

3.3. Data collection and instruments

3.3.1. Data collection methods

In order to obtain the representative and expressive samples for the requirements of the characteristics under consideration, the following data collection methods are used.

A. Interview

A non-structured interview was used as a pilot method to gather preliminary information about the qualitative characteristics of the quarry sites, social, traditional and urbanization activities that affect the quality and suitable areas to examine the effect of each external factor in the study area. In each sand production rivers five individuals (2 sand producers, 2 local consumers and 1 from the elder peoples in the society around the river basin) a total of 25 individuals have questioned the interview. Based on the responses of the interviewees, the factors that can affect the quality of river sand and the quarry points on which the sand was exposed for those factors were listed for further examination using field tests and laboratory.

B. Field test

Following the interview, visiting the situation in and around the river area, the river sand production methods and existing bottlenecks in quality of sand produced, was done by the researcher to check the presence and extent of factors affecting sand quality in a specified quarry point. In each sand source rivers, field tests were carried out to select the specific parts of the rivers on which the considering factors have existed with a measurable level and mark quarry points from which the samples were collected for the laboratory tests.

Based on the field test results, five factors were found as the influential issues on the quality of river sand. Those factors are; effect of human and animals, detergents and sewage effect, soil, leaves and flora, water flow of the river, and sand production, treatment, storage systems (Each factor is described in part 3.4). In addition, the controlled river points which were assumed to be free from the impact of different factors were selected in each river. All samples which were obtained from exposed areas by the factors has compared with the controlled samples. The traditional techniques used in the field were; observing the river sand characteristics and the exposure type, shrinking the sand by hand and observe if the particle sticks each other, and rubbing the sand with white cloth and observe if the color of cloth changes.

Based on the indication of field tests, 18 samples (15 affected by the five factors and 3 controlled samples) were collected from every single river. A total of 90 samples were collected from all the five sand production rivers as the laboratory test samples.

C. Laboratory tests

The laboratory tests were conducted in the sand samples which are collected based on the indication of field test results. The results of the experiment were used in evaluating the properties for a total of 90 sand samples (75 exposed areas by different factors and 15 controlled areas) which are collected from all the five rivers. The laboratory tests conducted in different sand samples were used to measure the difference between the properties of sand samples in two scenarios; the first was the five exposed conditions, while the other was controlled condition which is used as a baseline for the measures of change in property of sands by the actions of different factors. Experiments carried out in the laboratory for every point samples are;

- Silt content
- Specific gravity
- Bulking of sand
- Organic impurities
- Absorption capacity
- Unit weight and percentage void
- Particle size distribution and fineness modulus
- Compressive strength of concrete

The seven sand quality tests were conducted on a total of 90 samples which are collected from all five sand production rivers. While compressive strength tests were conducted on the concrete specimens produced using the mixed sand samples produced from the three sand source points in the specific factor. As a result, a total of 660 laboratory tests was conducted, 630 tests related to sand characteristics and 30 compressive strength of concrete tests.

D. GPS reading

In order to indicate the specific location of the sand production rivers, the GPS of the three points in the river basin were recorded.

3.3.2. Materials and tools

This study was mainly dependent on the representativeness of sand samples and the accuracy of the laboratory tests. For the best accomplishment of the study, the following materials and tools were used;

- Digging tools, hand shovels, and medium-size containers
- Pickup car for sand sample transportation
- White cloth for field tests
- Functional laboratory instruments
- Laboratory hand tools
- GPS reader, voice recorder, camera

3.4. Sample preparation

In all the five sand source rivers each factor has identified by using field tests and the river points has selected for both controlled and exposure scenarios. In identifying a controlled scenario, the area was checked to be free from any considerable disturbance by external factors. In order to obtain the controlled and exposed condition samples, field tests with multiple trials were used in each river points. In collecting samples from the exposed scenario, a single external factor was considered and tested by a field test for the presence and its significant effect on the sand property. In the sand source rivers, there was a number of external and environmental factors with various degree of influence. The considered factors in the study area was;

A. Access to human and animals and trucks

Based on the interview and field test results the quality of sand which is produced from the river sand has considered to be affected by the access of humans, and animals. This action includes the break downing the particles, contaminating the unnecessary materials and wastes in the river basin. With related to this factor, sand samples were collected from three different points in the single river basin and similarly from all rivers.

B. Detergents and sewage from the towns

In the river basin, there were uncontrolled activities including the washing of cloth, washing of cars and discharging of waste from the villages. These activities affect the content of river water and the properties of sand affected since the water is absorbed and at least in touch with the sand particles. The samples which are considered to be exposed to this factor have collected from fifteen cloth and car washing points from all five rivers.

C. Leaves and flora from the river surrounding area

The land around the rivers was used for recreation and in some rivers also for the agricultural purposes by irrigation and natural rainfalls, further, the river basin itself has grown small pants and vegetables. The sand deposited by the action of erosion before time and to be produced now has exposed and covered by soils and vegetables. The sand can contain soil particles, leaves, and plant decays at the time of production. The fifteen samples were collected from the areas where the plant's leaves and decays were found in the river basin.

D. Water flow of the river (including local soil)

In natural rivers, the flow of water is dependable on the rainfall in the river basin parts. The property of sand was expected to be changed since relatively high discharge flow of river disturbs the basin and it has contained non-crystalline soils, plants, stone, and even fragmented rocks parts. The fifteen samples exposed to this factor were collected in the morning next to the rainy night to obtain the disturbed representative samples.

E. Sand production, treatment and storage systems

The naturally available materials are not as pure as we can use in the concreting process so that the treatment of natural sand is necessary especially at the construction site level. For the purpose of understanding the production, treatment and storage effects, the sand collected from the river were treated by removing the silt and impurities and standardized to obtain the well-graded result and acceptable physical properties including fineness modulus, unit weight, specific gravity, absorption and bulking. A total of fifteen samples from all the five rivers was collected for the production, treatment and storage effects.

In addition to sand sample preparation, mix design of concrete was done for the compressive strength tests based on the C25 concrete production basis of the Ethiopian standard, by which 1:2:3 ratio of cement sand and aggregates have been mixed. For the purpose of concrete specimen production, the sand samples collected from three points of a specific sand factor were mixed and used. In order to observe the effect of sand characteristics on the compressive strength of concrete, a similar source crushed aggregate and Mosebo PPC cement with designation of 42.5 were used in all concrete specimens.

3.5. Sampling techniques

The required data used to identify the external factors which change sand quality was collected through laboratory experimental methods. Though there are a specific number of sand quarry rivers around Woldia, sand Source Rivers for this research was the nearest and mostly used as a supply for construction projects around Woldia town in specific and Amhara region in general. Since the river basins have not a considerably long supply length, the representative sand samples from a single quarry river was taken from three quarry points.

Sand samples have collected from five main sand supply rivers around Woldia town and in some north Wollo areas; namely Tikurwuha River, Alawuha River, Hormat River, Golina River, and Mersa Rivers. In order to obtain consistent and representative samples in all conditions, the sample sand was collected in no special factors are existed except the considered factor. A total of 90 samples (6 scenarios, 5 rivers and 3 points in each river) was collected from all five rivers to check the changeable properties of the sand. In each quarry point, a sample of 40kg of sand was collected.

In order to separate samples from each other, the designation was written in the sample containers. The designations used in the sample collection and experiments are;

- The river name was designated as AL, GL, HR, MR and TK for the Alawuha, Golina, Hormat, Mersa and Tikurwuha rivers respectively.
- The letter next to the name of the river designated to express the name of the factors either it is controlled or exposed by a symbolized factor. The letter C, H, D, L, W and P has used to express controlled samples, affected by 'access of human and animals', affected by 'detergents and sewage from the towns' affected by 'leaves and flora from the river surrounding area' affected by 'water flow of the river (including local soil) and affected by 'sand production, treatment and storage systems' respectively.

- The subscripts 1, 2, and 3 are an indication of the samples which were collected from three different points. The subscript numbers do not indicate the order or difference in the exposure level of samples.
- For instance, the designations ALC_3 indicates the sample collected from the third point of Alawuha river and the sample were not exposed for any factor (controlled), while the designation TKD_1 indicates the sample collected from the first points of Tikurwuha River and the sample were exposed to detergents and sewage from the towns.

3.6. Data analysis

An interview with individuals that are familiar with supplying, consuming and in touch with the sand river sites was applied to find the preliminary data and later to discuss the justifications of the obtained experimental value. The laboratory tests were conducted on the obtained representative sand samples by field tests. The test results of the laboratory has analyzed statistically using excel graphs and tables, in order to have a ready to discuss data in interpreting the parameters of sand quality variations for each factor.

The analyzed data which was collected by the laboratory tests and interviews have discussed in the way of identifying the difference between the controlled and each exposed sand samples and interpreting the current extent of sand quality changes including the possible prevention ways. In discussion and interpretation, the laboratory results have expressed by laboratory result reporting formats and evaluated based on the Ethiopian and ASTM standards.

4. Results and discussion

4.1. Introduction

The mass production of construction materials has a great role in supplying huge demands of the construction industry. Unlike materials produced at the factory level, the naturally available materials have many bottlenecks to be produced in a controlled environment recommended by standards. However, the Ethiopian construction industry has tried nothing in controlling the production process of natural construction materials. In this chapter, the collected data by using the field tests, interviews and laboratory tests which show the effect of different factors on sand quality, has been discussed and evaluated against the Ethiopian, ACI and ASTM standards. Since laboratory tests are efficient only if both controlled and exposed samples are representative of the existing situation in the sand river basin, nonstructural interviews and field tests have been used for a purpose of obtaining representative samples and clearing the data. The checklists which were considered in the nonstructural interview and field tests have shown in appendix 1. In addition, the three points of GPS reading of the sand source rivers has put in Appendix 7.

4.2. Research results

In order to investigate the factors that affect the quality of sand from rivers around Woldia town, eight different experiments were carried out in a total of 90 sand samples from five rivers with six different scenarios. The test samples were collected between the 4th of February 2019 and 6th of March 2019 in a reliable weather condition, while the laboratory tests were conducted between 11th of March 2019 and 5th of July 2019. The quantitative data of the average laboratory results of each river for different factors have shown below from table 4.1 to table 4.7, while the detailed laboratory test results, methods, and descriptions have attached in appendix 2 to appendix 6.

Table 4.1 experiment results of controlled sand samples

Experimets	Unit	ALC Mean	GLC Mean	HRC Mean	MRC Mean	TKC Mean	Mean	Min'm	Max'm
Silt content	%	2.837	3.2117	4.0467	3.87	2.9833	3.3897	1.17	5.56
Bulking of sand	%	12.83	18.97	16.347	16.07	18.047	16.453	11.11	21.21
Unit Weight	Kg/m3	1644	1632.2	1680.4	1679.8	1689.9	1665.3	1578.9	1709.1
Percentage Void	%	19.07	16.75	14.547	17.03	17.28	16.935	10.07	22.95
Specific Gravity	-	2.81	2.7967	2.7967	2.9367	2.7867	2.8253	2.62	3.06
Water Absorption	%	3.223	3.2733	2.6967	3.6	4.4667	3.452	2.66	5.93
Organic Impurity	Number	1	1	1	1	1.6667	1.1333	1	3
Fineness Modulus	-	3.257	3.07	2.8833	4.0033	4.0633	3.4553	2.63	4.22

Note: for organic impurity, the median was taken in place of the mean value.

Table 4.2 experiment results of sand samples exposed to human, animals, and truck action

Experimets	Unit	ALH Mean	GLH Mean	HRH Mean	MRH Mean	TKH Mean	Mean	Min'm	Max'm
Silt content	%	11.667	7.5833	7.66	5.57	8.945	8.285	4.5	15
Bulking of sand	%	19	20.8	21.603	22.347	21.217	20.993	17	23.45
Unit Weight	Kg/m3	1553.9	1389.2	1427.3	1469.8	1621.7	1492.4	1262	1711
Percentage Void	%	22.167	12.71	17.47	17.693	19.567	17.921	9.03	25.35
Specific Gravity	-	2.6233	2.6867	2.6767	2.7467	2.7333	2.6933	2.6	2.81
Water Absorption	%	5.1667	5.4833	3.3733	4.57	5.075	4.7337	3.15	7.15
Organic Impurity	Number	3.3333	2.6667	3	3.3333	2.3333	2.9333	2	4
Fineness Modulus	-	2.6167	2.2367	2.2467	2.0433	2.7	2.3687	1.96	2.94

Note: for organic impurity, the median was taken in place of the mean value.

Table 4.3 experiment results of sand samples exposed to detergent and sewage flow

Experimets	Unit	ALD Mean	GLD Mean	HRD Mean	MRD Mean	TKD Mean	Mean	Min'm	Max'm
Silt content	%	10.833	6.4333	10.207	6.8433	8.8967	8.6427	5.45	11.5
Bulking of sand	%	19.667	22.633	20.41	19.563	19.38	20.331	17.54	25.85
Unit Weight	Kg/m3	1431.3	1612.5	1735.1	1679.2	1701.1	1631.8	1309	1782.3
Percentage Void	%	18.807	13.917	16.173	18.12	15.753	16.554	13.17	20.75
Specific Gravity	-	2.55	2.56	2.6567	2.6433	2.6733	2.6167	2.55	2.71
Water Absorption	%	6.82	5.5833	4.0233	3.5167	4.7	4.9287	3.12	8
Organic Impurity	Number	4.3333	3.6667	2.6667	3.6667	3	3.4667	2	5
Fineness Modulus	-	2.9933	2.8467	3.0133	3.7333	3.15	3.1473	2.78	3.9

Note: for organic impurity, the median was taken in place of the mean value.

Table 4.4 experiment results of sand samples exposed to the water flow of the river

Experimets	Unit	ALW Mean	GLW Mean	HRW Mean	MRW Mean	TKW Mean	Mean	Min'm	Max'm
Silt content	%	13.5	7.75	8.8833	7.0767	18.15	11.072	1.25	21.5
Bulking of sand	%	20	21.45	25.617	19.883	20.75	21.54	16.25	27.95
Unit Weight	Kg/m3	1445.2	1502.7	1568.1	1476.2	1507.8	1500	1324.3	1709.6
Percentage Void	%	27.187	20.717	19.033	25.39	20.26	22.517	10.94	31.28
Specific Gravity	-	2.5333	2.6667	2.5767	2.6733	2.6333	2.6167	2.45	2.75
Water Absorption	%	7.0833	4.4967	3.39	3.5767	5.6167	4.8327	2.95	9.5
Organic Impurity	Number	3.6667	3.3333	3	3.6667	3.3333	3.4	3	4
Fineness Modulus	-	3.55	4.49	3.9933	4.4633	3.3	3.9593	1.98	4.65

Note: for organic impurity, the median was taken in place of the mean value.

Table 4.5 experiment results of sand samples exposed to leaves and flora

Experimets	Unit	ALL Mean	GLL Mean	HRL Mean	MRL Mean	TKL Mean	Mean	Min'm	Max'm
Silt content	%	9.3167	9.517	10.837	10.267	10.24	10.04	6.87	16.3
Bulking of sand	%	17.5	19.77	22.96	19.81	20.243	20.06	16	24.65
Unit Weight	Kg/m3	1428.9	1380	1428.7	1472.2	1435.4	1429	1297.1	1545.8
Percentage Void	%	16.713	15.76	14.39	17.41	17.533	16.36	12.93	19.54
Specific Gravity	-	2.5267	2.617	2.63	2.5967	2.63	2.6	2.43	2.68
Water Absorption	%	4.9667	4.193	3.2933	5.01	4.1367	4.32	3.01	6.15
Organic Impurity	Number	4	3.667	2.6667	3.3333	3.3333	3.4	2	5
Fineness Modulus	-	3.2867	2.8	2.29	2.8033	2.82	2.8	1.94	3.42

Note: for organic impurity, the median was taken in place of the mean value.

Table 4.6 experiment results of sand samples exposed to production treatment and storage

Experimets	Unit	ALP Mean	GLP Mean	HRP Mean	MRP Mean	TKP Mean	Mean	Min'm	Max'm
Silt content	%	0.1667	0.3267	0.2833	0.2667	0.0833	0.2253	0	0.75
Bulking of sand	%	10.283	11.95	11.163	9.7667	11.113	10.855	8.5	15.85
Unit Weight	Kg/m3	1697.4	1737.4	1765.5	1789.7	1803.6	1758.7	1687.8	1834.1
Percentage Void	%	15.683	12.533	11.87	9.9967	10.92	12.201	8.45	16.85
Specific Gravity	-	2.8533	2.8067	2.87	3.0467	3.0567	2.9267	2.79	3.15
Water Absorption	%	2.1	2.3433	2.3467	2.18	2.4567	2.2853	2	2.55
Organic Impurity	Number	1	1	1	1	1	1	1	1
Fineness Modulus	-	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8

Note: for organic impurity, the median was taken in place of the mean value.

NB: The number of tests was 15 in each experiment.

Table 4.7 experiment results of compressive strength produced from different sand samples

No	Exposure level	Unit	days of measurement	Sand source rivers					Mean	Min'm	Max'm
				AL Mean	GL Mean	HR Mean	MR Mean	TK Mean			
1	Controlled	MPa	7	18.2	13.6	18.6	18.1	16.4	16.98	13.6	18.6
			14	25.9	21.1	24	23.2	23.7	23.58	21.1	25.9
			28	29	26.8	26.5	27.5	27.6	27.48	26.5	29
2	Exposed to human and animal action	MPa	7	12.3	11.8	13	10.8	14.5	12.48	10.8	14.5
			14	20.4	18.5	18.1	19.9	20.7	19.516	18.1	20.7
			28	25.6	24.3	22.6	23.1	24.5	24.028	22.6	25.64
3	exposed to detergent and sewage flow	MPa	7	12.3	13.7	14.3	11.93	15.2	13.486	11.93	15.2
			14	18.4	18	18.7	20.8	21.1	19.394	17.97	21.1
			28	20.7	22	20.8	22.9	22.9	21.86	20.7	22.9
4	exposed to water flow of the river	MPa	7	13.3	14.7	15.8	14.5	13.3	14.32	13.3	15.8
			14	21.6	20.6	19.8	21.5	18.3	20.36	18.3	21.6
			28	25.4	24.9	24	25.6	21.6	24.294	21.6	25.6
5	exposed to leaves and flora	MPa	7	14.8	12.7	15.1	13.1	14.7	14.08	12.7	15.1
			14	23	20.1	19.9	19.5	20.1	20.52	19.5	23
			28	27	23.8	23.5	23.4	23.6	24.26	23.4	27
6	exposed to production treatment and storage	MPa	7	20.8	20.2	24	23.6	22.9	22.294	20.2	23.97
			14	30.8	26.8	33.1	30.4	32	30.62	26.8	33.1
			28	37.2	31.9	39.1	35.6	38	36.36	31.9	39.1

NB: The number of tests was 5 in each experiment.

4.3. Discussion and interpretation

In this section, the result of the interview, field tests, and laboratory tests have discussed depend on the effect and magnitude of different factors is collecting the representative samples in each scenario and comparing the exposed results with the controlled (not affected) sample results. Furthermore, both controlled and exposed sample characteristics have evaluated against the recommended standards.

4.3.1. Sand production system in the area

4.3.1.1. River sand producers

As observed in the sand production rivers (shown in Figure 4.1), the production process was limited to the direct taking of accumulated sand or digging out from the flow of river basins.

The sand produced in the river has mostly exposed to different factors by the actions of water, wind, animals, and different social activities. In most river quarries, the sand producers are locally organized peoples by small and micro enterprises office. On average there were 30 to 40 groups in each sand source rivers with five members in a group. Since the production of sand in each river has done by the organized groups, the river was divided and given for the groups with 150m to 300m length of the stream. Most of these members have not any certificate in related fields and did not take any training about sand production and quality control mechanisms, though some of the members have completed the Ethiopian secondary school levels. Further, the sand process was undergone manually in traditional ways without using any machinery except the hand shovels and digging tools.

Figure 4.1 production and transportation of river sand

4.3.1.2. Local regulatory bodies

As the producers express, the local regulatory have not administered the sand production process except the licensing and tax collecting tasks by the trade and revenue offices. There were a number of sand producer groups with five members in each river, though there are some individuals that produce sand with no license from the local regulatory bodies. As shown in Figure 4.2 most producers does not take care for their health and safety problems which can be caused by the process, though the working area needs personal protective equipment to protect their selves from dust and shaped particles, In addition the environmental issues have not given an attention by both the producers and the regulatory.

Figure 4.2 sand production without any protective equipment

4.3.2. Common practices on sand producing rivers

The sand production rivers have the water flow in most seasons of the year, though the flow water quantity was dependable on the rainfalls in and around the river basins. For this reason, the river water is an alternative source of water for the day to day consumptions of the community. Since the economy of the peoples around the river basin has mainly concentrated on the agriculture and agricultural product markets, peoples around the river has used the river water for different in-home and out of home activities. The following are the commonly observed practices around the river basin.

4.3.2.1. Agricultural activities

As shown in Figure 4.3, agriculture has practiced using the natural rainfall system in the study area. Now a day, the river waters and the underground water of some areas lead to be used for irrigation to produce different vegetables and fruits in the three Raya Kobo's river areas, namely Alawuha Golina and Hormat rivers. Most of the farmers around the river basins have used irrigational agriculture using underground and river water. The three sand producing rivers used for an irrigational purpose also used as a garden and recreational areas for the wedding and other ceremonies in the area. In addition to farming practices, people use the river as a water source for their consumption in the home and for their cattle in the river basin.

Figure 4.3 irrigation channel to flow river water to the farm

4.3.2.2. Sewage and dirt removal activities

The river basin portions near the small towns and villages mostly consumed for the purpose of cloth washing and car washings. In addition to consuming the river water, the washing practice can releases the organic dirt to the river flow as sown in Figure 4.4. This can affect the river sand obtained below the interference points to contain those organic impurities. Furthermore, dirt particles can be sourced directly from the town since there was not common garbage to enclose the dirt in the towns and villages.

Figure 4.4 river as used for water supply and car washing

4.3.3. Potential factors on river sand quality

4.3.3.1. Human, animal and truck action

Introduction

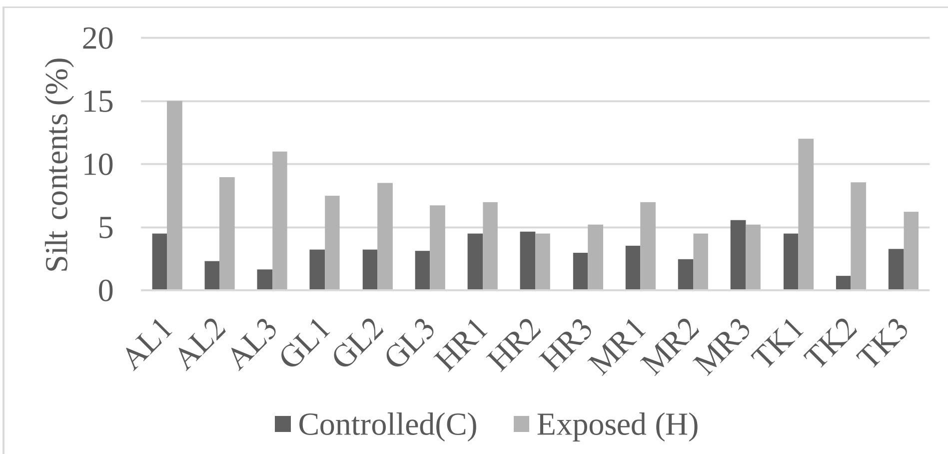
As shown in Figure 4.5, the disturbance in the river basin was common for the purposes of; human transport for sand and water access, animal's access to the river water and grass around the rivers and truck transport to load the produced river sand. In this manner, the accessible portion of the river sand was broken down to the smaller sizes, in which the particles of sand were changed to a lesser size than 75µm or to the silt sizes. The smaller sizes could be directly collected from the place for construction purposes or can be transported by water flow to the lower basin on which sand production takes place.

Figure 4.5 a mini road for human, animal, and cars on the river sand supply areas

In addition to fining the sand particles, the human, animals and truck action had the effect of disturbing the possible graded distribution of natural sand by moving the particles away or by mixing other natural things to the river sand. For numerical test results of controlled samples and samples exposed to humans, animals and truck action, see table 4.1 and 4.2. The main effects of humans, animals and truck action have discussed below.

A. Silt content

In a controlled (normal) situation the average silt content of the river sand samples was between 2.8% and 4.1% which was recorded in Alawuha and Hormat rivers. All the river sand samples were observed with no significant difference in each other and have values within the allowable ranges of the recommended standards. On another side, the silt content of the sand samples which are collected from the exposed area by the human and animal action has a significant difference when compared to the controlled samples. As shown in graph 4.1, in an exposed situation sand from Alawuha (11.7%), Golina (7.6%), Hormat (7.7%) and Tikurwuha (9%) rivers has significantly higher average silt content above the allowable amount which is 6% as recommended by Ethiopian standard, however, numerically Alawuha river sand contains the maximum silt content (≈12%). As shown in table 4.2, the average silt content of Mersa river samples (5.6%) was within an allowable maximum value, it was recorded to be the minimum average silt content, though it nearly equals the maximum allowable value.

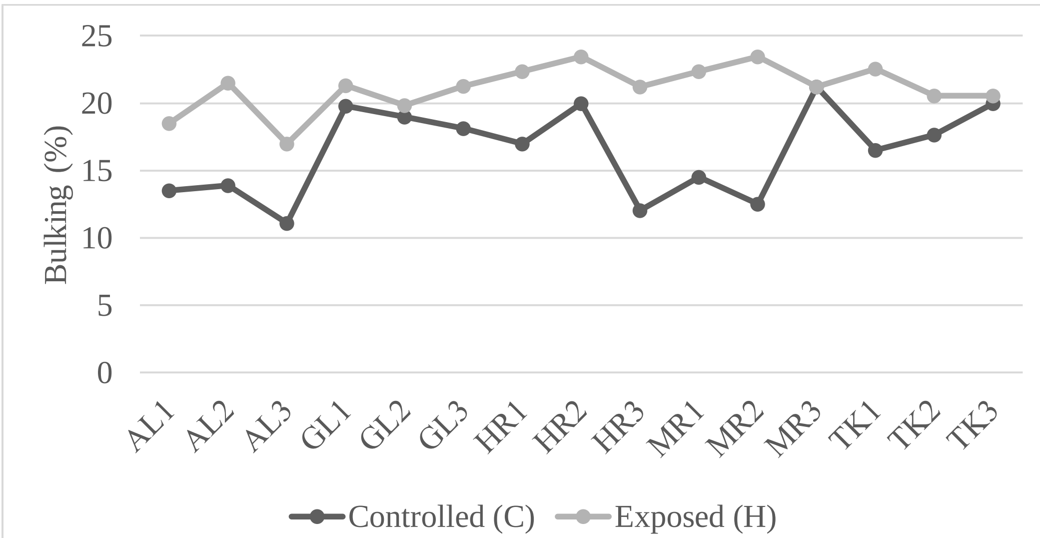


Graph 4.1 silt content of controlled and exposed samples for human, animal and truck action

Even though the sand samples within the controlled (normal) situation were not perfectly free from silt and clay, sand samples that were exposed to human and animal action contained more silt content than the controlled samples. In the normal situation, the silt content of most river sand samples were within the recommended standards and lower than the rift valley sand samples which are the most common source of sand for Addis Ababa city and its environs, while the exposed samples contained silt contents more than the recommended allowable amount in most river sources.

B. Bulking of sand

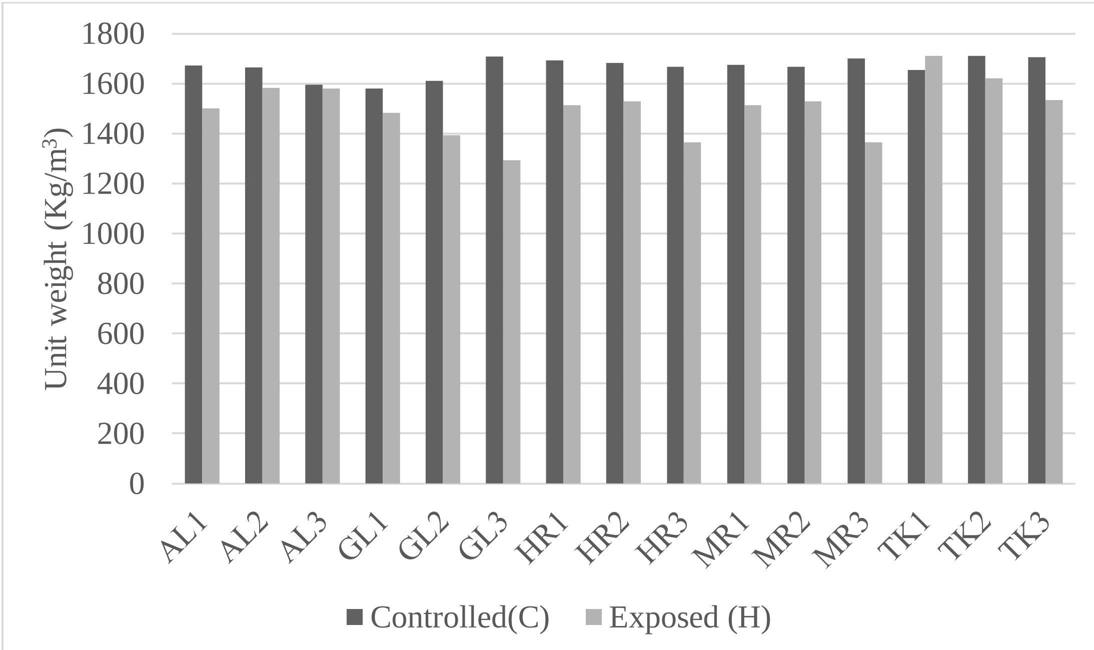
Based on the laboratory results, an average bulking of sand samples from the controlled environment were between 12.8% (Alawuha river) and 19% (Golina river) which are measured from the Alawuha and Golina rivers respectively, while the average bulking of sand samples from exposed environment was recorded in Alawuha river (19%) as a minimum value and Mersa river (22.4%) as a maximum value. Though the bulking of sand is not the perfect measure of sand quality, it is clear that the action of humans, animals, and trucks has its own effect on the particle size distribution and disturbance of the sand samples, see graph 4.2.



Graph 4.2 bulking of controlled and exposed samples for human, animal and truck action

C. Unit weight and percentage void

The laboratory test for unit weight was conducted based on the recommended procedures of ASTM C 29 and C 128. As shown in graph 4.3, the unit weight of sand samples which was collected from the controlled (normal) scenario has a total average unit weight of 1665.3Kg/m^3 while the total average unit weight of sand samples has collected from the exposed scenario was 1492.37Kg/m^3. The minimum average value from the controlled sand sample results was 1632.22Kg/m^3 and the maximum average value was 1689.9Kg/m^3, while the minimum average value from the sand samples of exposed to human and animal action was 1389.2Kg/m^3 and the maximum average value was 1621.7Kg/m^3. The unit weight in both situations was observed within an acceptable range for the normal weight concrete which is 1200-1750Kg/m^3 as recommended in ASTM C 29 and C 128. It was clearly observed in the laboratory results that, the unit weight of most exposed samples was lower than the corresponding samples which are collected from a controlled situation. It may be caused by the presence of different sandy loam and small particles which is broken down by the action of humans, animals and sand loading trucks.

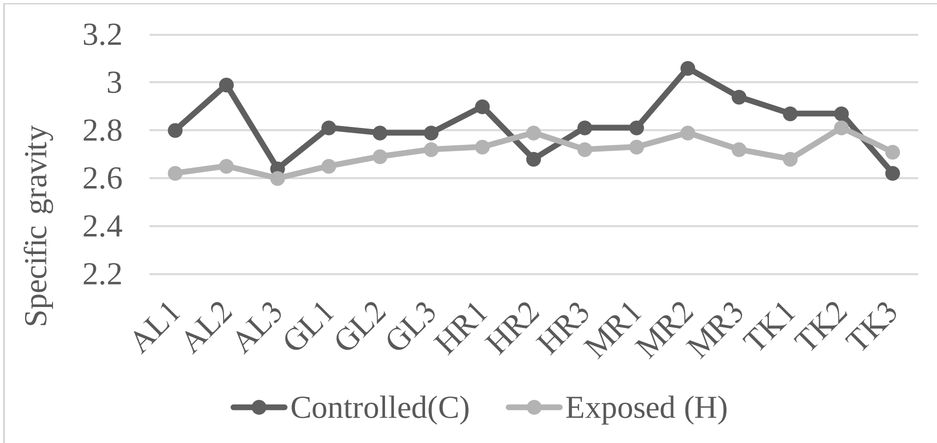


Graph 4.3 unit weight of controlled and exposed samples for human, animal and truck action

The total average percentage void of the controlled samples (which was conducted based on the procedures of ASTM C1252) was recorded as 16.94% with a minimum and maximum average percentage void values of 14.55% and 19.1% respectively, while the exposed samples have 17.9% average value with the minimum and maximum void values of 12.71% and 22.2% respectively. Based on the laboratory test results, it was clear that the action of human and animal has a significant effect in disturbing the particle size distribution since the void can be significantly lower in a well-graded sand samples.

D. Specific gravity

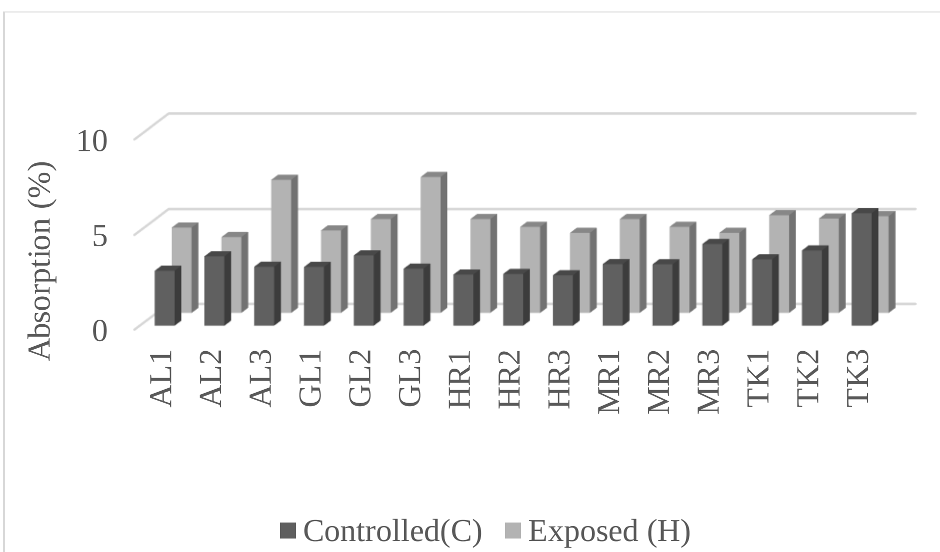
The laboratory results of the specific gravity which was conducted (as detailed in ASTM C 128 and ACI 1991). As shown in graph 4.4, the controlled samples have the total average specific gravity of the controlled samples were 2.8 with the minimum and maximum average values of 2.79 and 2.94 respectively, while the total average specific gravity of exposed samples were recorded as 2.69 with the minimum and maximum values of 2.62 and 2.75 respectively. Based on the laboratory results, the action of human, animals, and trucks were clear to decrease the specific gravity of sand by releasing different non-sand soil particles to the sand source. Since the small difference in a specific gravity has a significant effect on the characteristics and usage of sand sources.



Graph 4.4 specific gravity of controlled and exposed samples for human, animal and truck action

E. Water absorption

The water absorption test was conducted based on the details of ASTM C128 and ACI procedures. As shown in graph 4.5, the total average results of the controlled river sand samples were recorded as 3.45% with the minimum and maximum average values per rivers was 2.7 and 4.5% respectively, while the total average water absorption of the exposed river sand samples were recorded as 4.7% with the minimum and maximum values of 3.4% and 5.5 % respectively.

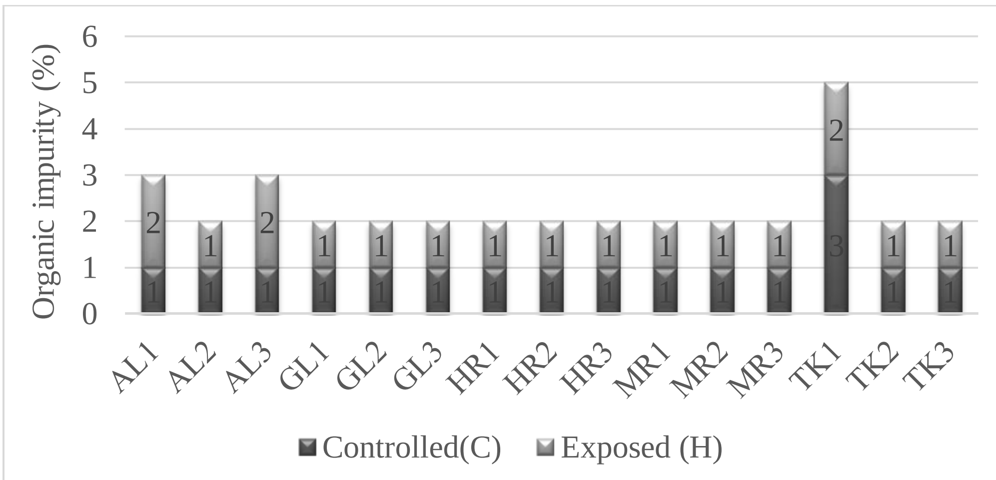


Graph 4.5 absorption of controlled and exposed samples for human, animal and truck action

It was clear that the water absorption was significantly affected by the actions of human and animal action on sand samples. This may be because of the presence of uncontrolled clay and small size sand particles which can be produced by the smash action on the sand.

F. Organic impurity

As shown in graph 4.6, the organic impurity of the sand samples was not significantly affected by human, animal and truck action.



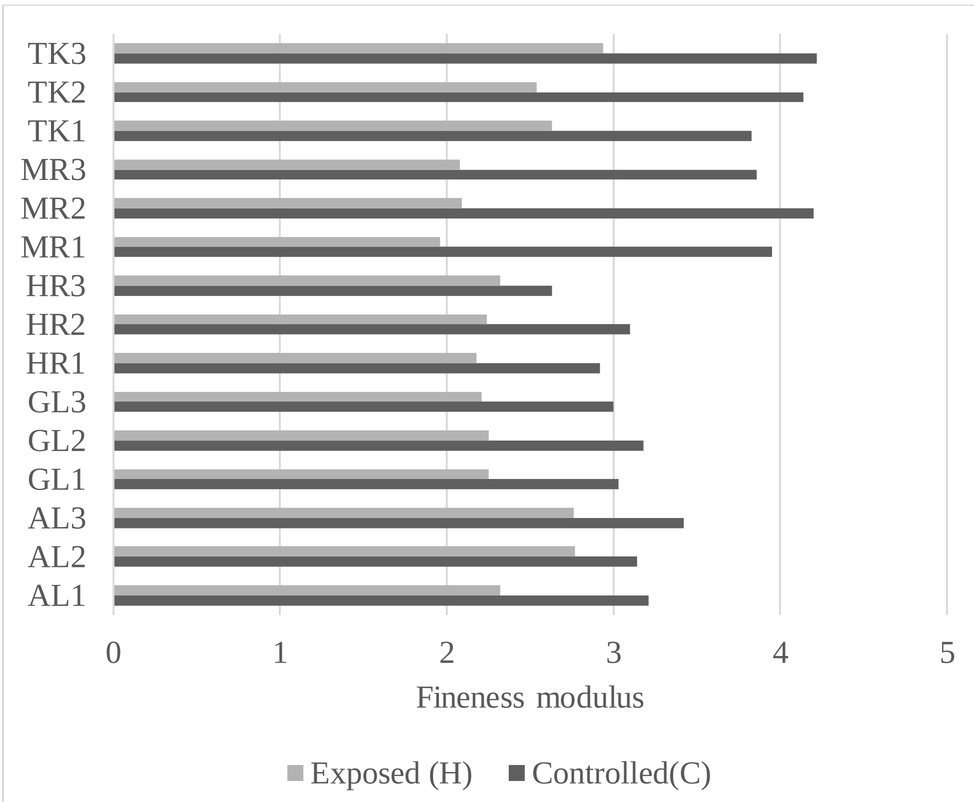
Graph 4.6 organic impurity of controlled and exposed samples for human, animal and truck action

The individual color values in AL1, AL3, and TK1 was recorded as 2, while TK1 was recorded as 3 in a controlled situation. However, an organic impurity of both controlled and exposed samples was within the recommended standards of ASTM C 40 in a color test indication, in which a colorimetric indication below 3 is acceptable for construction purposes.

G. Sieve analysis and Fineness modulus

Fineness modulus

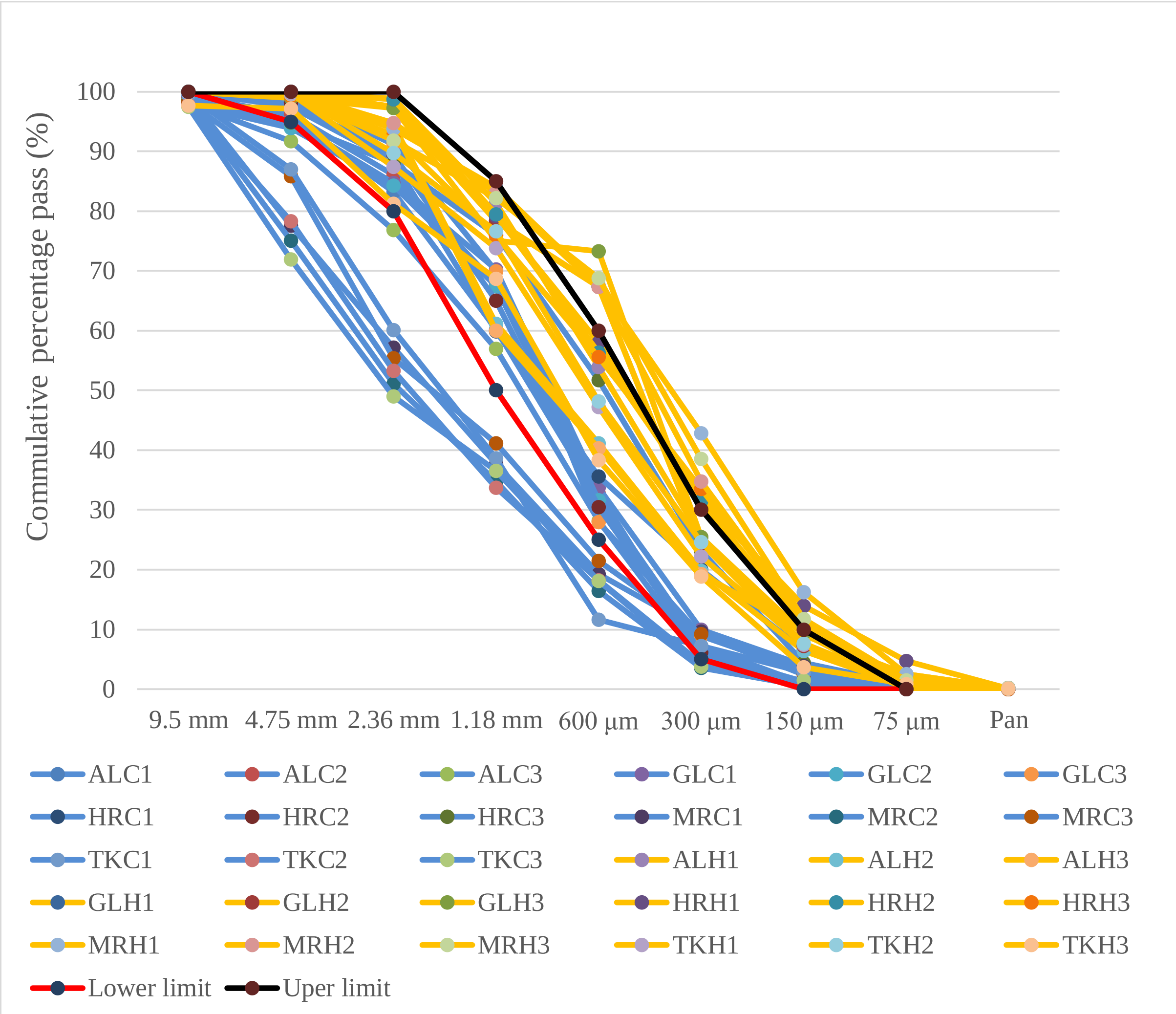
As shown in graph 4.7, the total average fineness modulus of the controlled samples was recorded as 3.45 with the minimum average value of 2.9 and average maximum value of 3.5, while the total average fineness modulus of the exposed samples was recorded as 2.4 with the minimum value of 2.04 and the maximum value of 2.7. There was a significant difference within the controlled and exposed samples with a range of 0.5 on the average values. In the controlled situation, the average fineness of Golina and Hormat river sand samples were observed to be above the recommended lower limit, 2.3, while Alawuha, Mersa and Tikurwuha river sand samples have an average fineness modulus above the recommended upper limit, 3.1. In the exposed situation, the average fineness modulus of sand samples from Golina (2.2), Hormat (2.3) and Mersa (2.04) rivers were lower than the allowable lower limits of the ASTM C33 recommendation which is between 2.3 and 3.1. It was clear from the laboratory results that, the human, animal and truck interaction on the sand source rivers has a breaking down effect on the sand samples.



Graph 4.7 fineness modulus of controlled and exposed samples for human, animal and truck action

Sieve analysis

As shown in graph 4.8, the particle size distribution of the controlled samples was observed that, half of the sand samples were below the lower limits of percentage pass in the sieve sizes of 300µm to 9.5mm, while the particle size distribution of sand samples in the sieve sizes below 300µm has fallen between the recommended lower and upper limits of percentage pass. In the exposed sand samples, most of the samples were observed within the recommended intervals of percentage pass in the sieve sizes above the 1.18mm, while the percentage pass of the sand samples in sieve sizes of below 1.18mm the percentage pass of the samples were above the upper limits of the recommended standard as detailed in ASTM C33.



Graph 4.8 sieve analysis of controlled and exposed samples for human, animal and truck action

4.3.3.2. Detergent and sewage from the towns

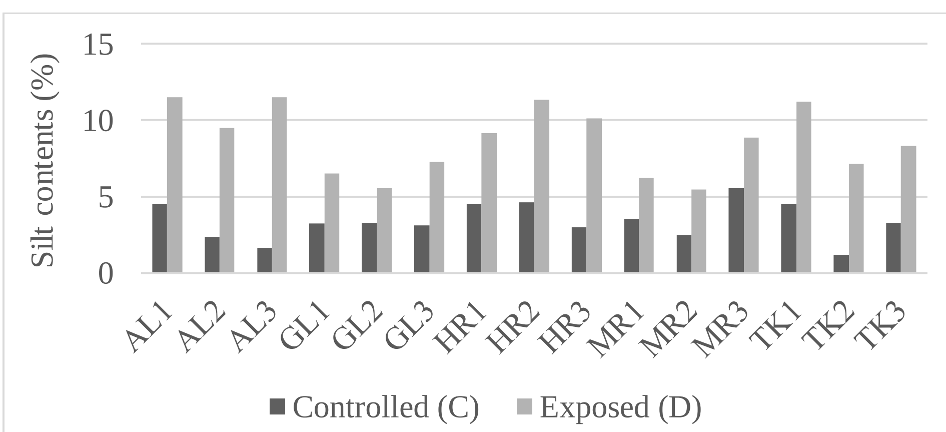
Introduction

In the river areas where there is an existing rock base or artificial concrete structures, the washing of clothes, cars and different materials has been undergone as shown in Figure 4.6. In addition, the dry and fluid wastages were removed to the river basins with no attention by the regulatory bodies. In these cases, the detergents from washing and the sewages from the towns flowed to the lower basins on which the sand production was undertaken. The organic impurities released from the sewages has a probability of mixing the river sand production areas, on which the chemical impurities could be mixed and changed the characteristics of sand product. For numerical test results of controlled samples and samples exposed detergent and sewage action, see table 4.1 and 4.3. The following were the main effects of the detergent and sewage action on the quality of sand.

Figure 4.6 washing area for humans, cloth and cars on the river sand supply areas

A. Silt content

As observed in the findings of the research, the silt content of the river sand samples was significantly affected by the actions of detergents and sewage flow from the towns. As shown in graph 4.9, this factor has increased the total average silt content of sand samples more than a double of the controlled sand samples.

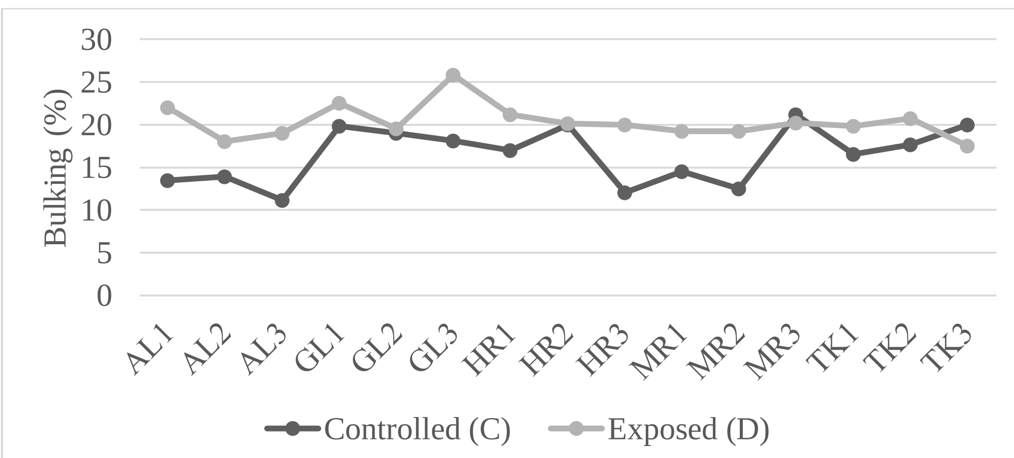


Graph 4.9 silt of controlled and exposed samples for detergent and sewage from the towns

The average silt content observed in the controlled samples was 3.4% and the exposed condition has changed the amount to the sever silt content which was 8.6% on average of all exposed samples. In an exposed condition the silt content of individual samples was recorded as higher as 11.5% which is more than the doubles of the allowable maximum silt content in Ethiopian standard, which is 6%. It was clearly understood that the detergent and sewage were contained the small particles which have not characterized as the sand particles, those may be from the waste of villages and from washing practices of community on the river basin.

B. Bulking of sand

As shown in graph 4.10, the detergent and sewage flow in the sand producing rivers has slightly changed the average bulking of sand.

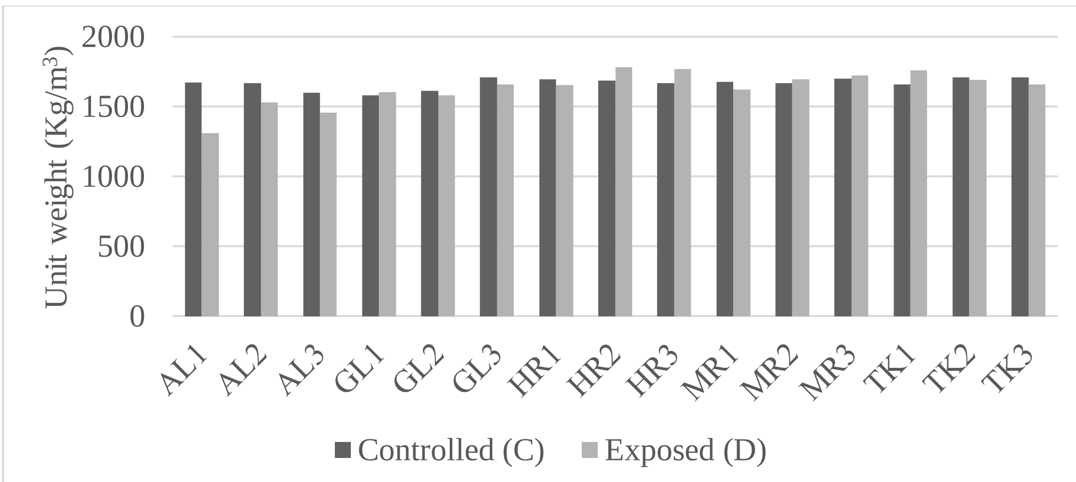


Graph 4.10 bulking of controlled and exposed samples for detergent and sewage from the towns

The bulking value of controlled sand samples were widely diverse in the ranges of 10, between 11.11% (minimum) and 21.21% (maximum) value of bulking. While in the scenario of exposed to detergent and sewage samples, the average bulking of sand was recorded within the range of 3, in the interval between 19.4% and 22.6%, though in the individual test result the bulking of sand was not significantly diverge.

A. Unit weight and percentage void

As shown in graph 4.11, the presence of detergent and sewages in the sand producing rivers were not shown a significant effect on the unit weight of the sand samples, however, it has changed the average unit weight from 1665.3Kg/m^{3}to 1631.85Kg/m^3. The ranges of unit weight in the controlled situation was observed between 1632.22Kg/m^3 and 1689.9Kg/m^3, while the unit weight of the exposed situation was between 1431.3Kg/m^3 and 1735.1Kg/m^3. Though the factor slightly decreases the average unit weight of sand in the average values of 34Kg/m^3, the test result shows that the individual unit weight value of both controlled and exposed sand samples were not linear and difficult to interpret the clear difference in terms of the exposure impacts.



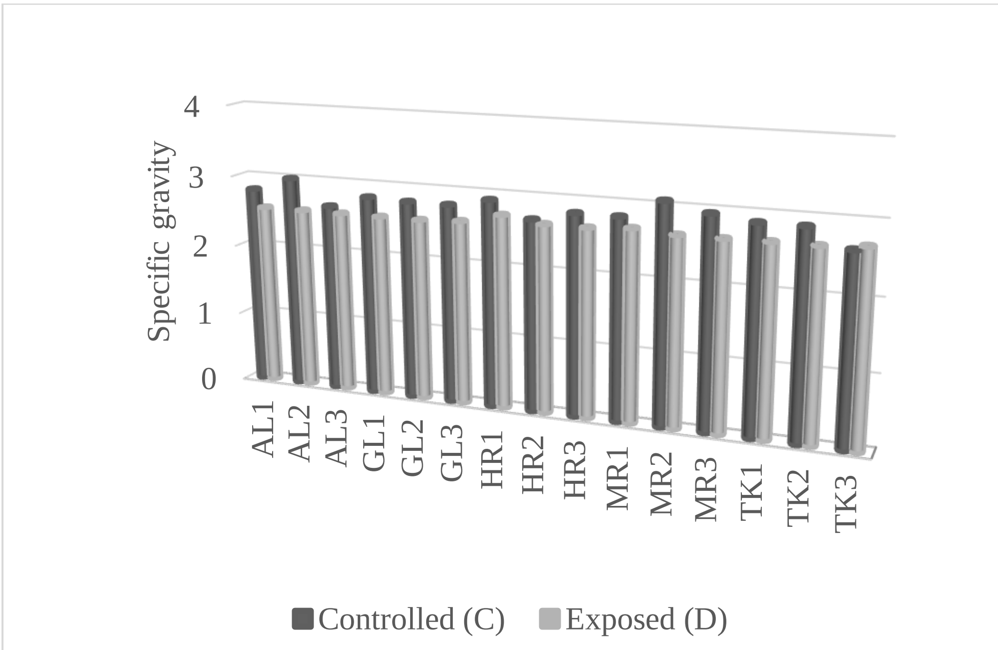
Graph 4.11 unit weight of controlled and exposed samples for detergent and sewage from the towns

Even though the individual river sand samples of HR2, HR3, and TK1 of exposed scenario shows the unit weight slightly above the recommended upper limit, other sand samples in both scenario falls in the recommended intervals as detailed in ASTM C 29 and C 128, which is between 1200Kg/m^3 and 1750Kg/m^3 for a normal weight concrete.

As observed in laboratory results which were conducted based on the details of ASTM C 1252, the percentage void of the sand samples was not significantly affected by the presence of detergent and sewage in the sand producing rovers. The recorded average void was 16.9% in the controlled situation and 16.6% in the exposed situation, though the individual measurements of void were highly diverse throughout the river sand samples.

B. Specific gravity

The laboratory results which were conducted based on the details ASTM C 128 show that the specific gravity of the river sand samples was significantly affected by the detergent and sewage flow in the sand source rivers basins. As shown in graph 4.12, the factor had the effect of decreasing the specific gravity of sand samples from a total average of 2.83 to 2.62, however, all individual samples were within the recommended standard intervals of ASTM C 128, which is from 2.3 to 3.0 for a normal weight concrete aggregate.

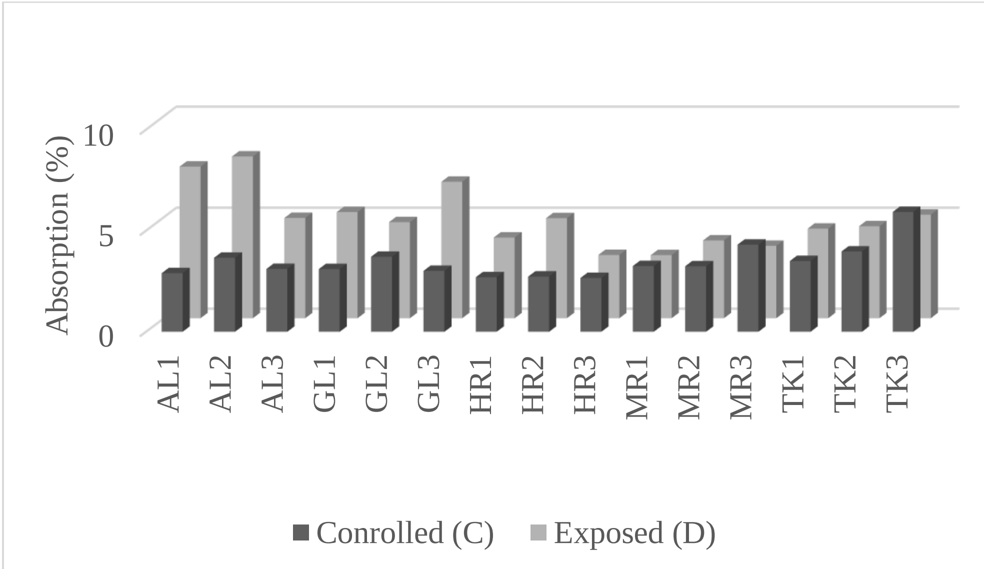


Graph 4.12 specific gravity of controlled and exposed samples for detergent and sewage from the towns

In respect to unit weight results which were not significantly affected by the factor, the results of the specific gravity test were not expressing the correlation with the unit weight. It may be because of the duct releases which probably produced by the detergent and sewage action on the river flow.

C. Water absorption

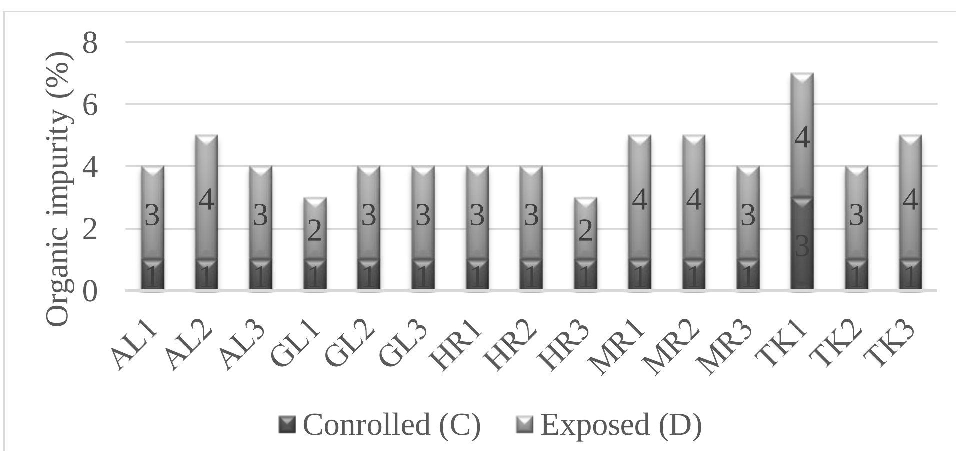
Water absorption tests of the river sand samples were conducted as detailed in ASTM C128. The laboratory result (as shown in graph 4.13) shows that the water absorption of sand samples was not significantly affected by the detergent and sewage action, it was varied from 3.45% in a controlled situation to 3.12% in exposed situation. It was clear that the water absorption of samples with non-sand particles was lower than the controlled sand particles. However, in both controlled and exposed scenarios, the water absorption of the river sand samples was lower than the recommended upper limit.



Graph 4.13 water absorption of controlled and exposed samples for detergent and sewage from the towns

D. Organic impurity

As shown in graph 4.14, organic impurity of the river sand samples was affected by the actions of detergent and sewage flow. The sand samples in exposed condition were containing impurity above the recommended amount in the individual river sand samples of AL1, MR1, MR2, TK1, and TK3 river points, while in Golina and Hormat river samples there was a color indication between 2 and 3. Based on the ASTM C 40 recommendation sand samples above the acceptable color value shall not be used for construction without treatment.

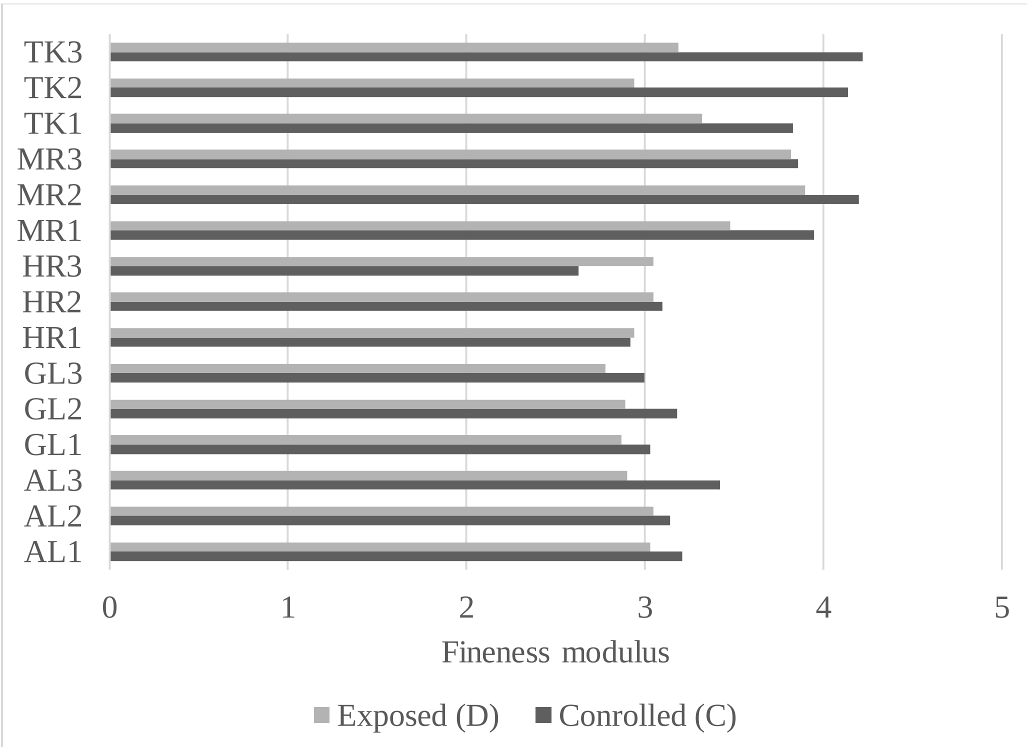


Graph 4.14 organic impurity of controlled and exposed samples for detergent and sewage from the towns

E. Sieve analysis and fineness modulus

Fineness modulus

As shown in graph 4.15, the total average fineness modulus of the sand samples was not significantly affected by the detergent and sewage which was 3.5 in controlled and 3.2 in exposed situations.

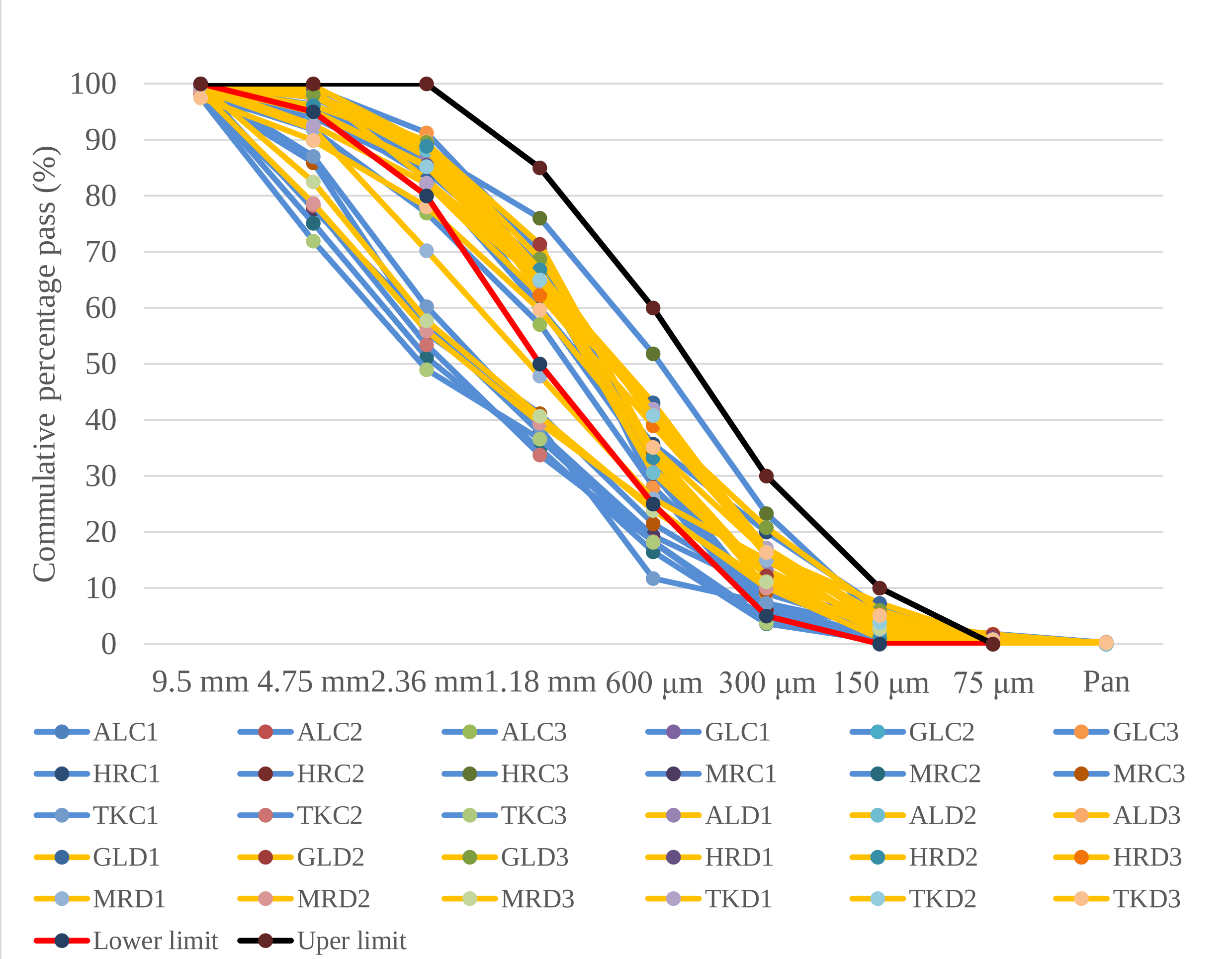


Graph 4.15 fineness modulus of controlled and exposed samples for detergent and sewage from the towns

Though in some individual sand samples fineness modulus was observed to be affected by detergent and sewage especially in TH2, TK3 sand samples, it could not assure to be significantly affected since the gradation of a single sand source cannot be similar in test results different samples. As shown in graph 4.15, the sand samples were coarser with the individual fineness modulus of greater than 2.9 in both scenarios. In both situations, Mersa and Tikurwuha rivers have fineness modulus higher than the recommended upper limits of ASTM C33 (2.3-3.1), so that, it may not be used for a normal strength concrete.

Sieve analysis

As shown in graph 4.16, the particle size distribution of the river sand samples was not significantly affected by the detergent and sewage action in the river area.



Graph 4.16 sieve analysis of controlled and exposed samples for detergent and sewage from the towns

To some extent, the percentage pass of sand samples was increased within the upper limit by the actions of detergent and sewage. It was clear that half of the sand samples in both scenarios were observed to be below the lower limits of the recommended ASTM C33 standard. Though there were some variations in the particle size distributions of sand samples within the two different scenarios, it could not assure to be the effect of sewage and detergent, since the distribution can be differ based on the ignorable errors in sampling.

4.3.3.3. Water flow of the river basin

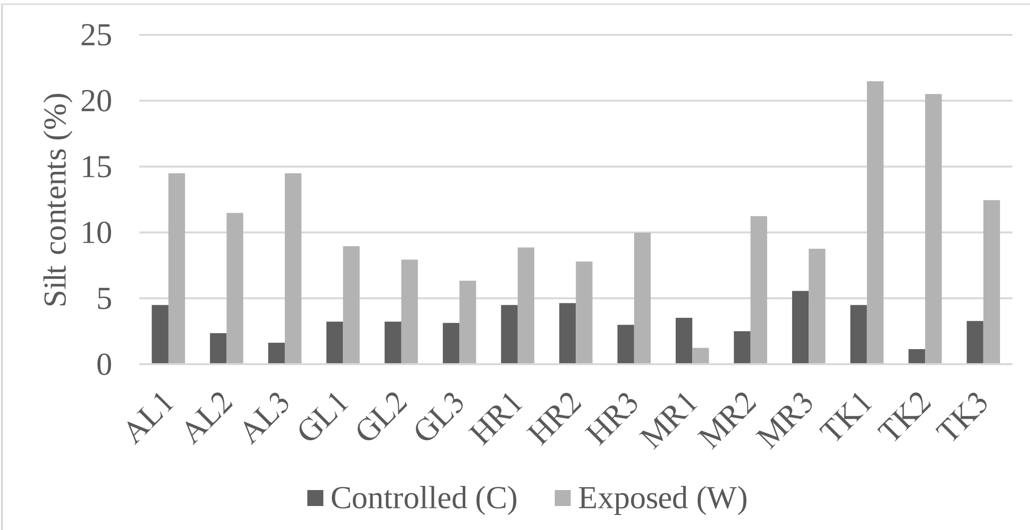
Introduction

As shown in Figure 4.7, the water flow of the river in the rainy days was very high even the sand production process was difficult until the flow becomes lower for the access of producers. In the situations when the flow in the river becomes huge, the flow could deposit aggregate types, wood portions, different soil types, and granular materials. The sand accumulated or collected immediately after the flow has stopped was contained these materials in a considerable amount. In this case, the sand has a coarser or finer nature depend on the materials deposited with sand and a high amount of silt and clays was observed on the basin. The quality of river sand in the presence of high water flow in the basin has differed from the sand in the minimum flow condition since the presence of the erodible materials could change the characteristics of sand. For numerical test results of controlled samples and samples exposed water flow of the river, see table 4.1 and 4.4. The existence of high water flow in the rivers can have the following effect on the sand quality.

Figure 4.7 sand source rivers after high water flow in the basin

A. Silt content

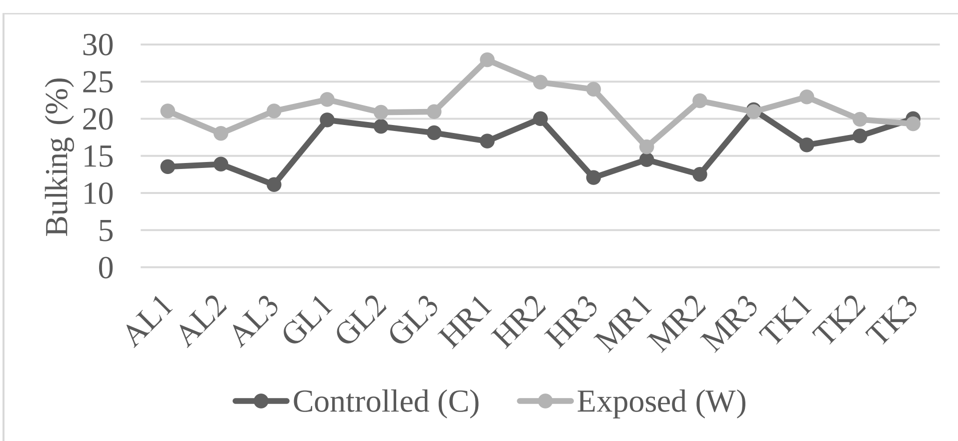
The flooding water in the river can be sourced from the river area or in the highlands places around the river basin area. The flow from the highland place was mostly caused by the natural rainfall, while river basins have their own water flow in most times of the year, however, the charge may be lower depending on the amount of rainfall around the basins. In the time when the flow was higher, the water has carried the soils, clays, granular and different plant roots by mixing the sand. As shown in graph 4.17, the silt content of the sand samples which was collected from the exposed points had shown a significant difference from the controlled sand samples. The average silt content of the exposed samples was as high as 18% in Tikurwuha river samples, while it was as low as 1.25% in a single sample of Hormat River however the average silt of this river was 7.1%. The maximum silt content in the controlled samples was 5.6%, which is within the recommended intervals of the Ethiopian standard. It was clear that the water flow of the river could, unfortunately, wash the sand by the impure flooding water, though there was a lower chance of obtaining the washed sand since it could later mixed with the clay and salt accumulations.



Graph 4.17 silt content of controlled and exposed samples for water flow of the river basin

B. Bulking of sand

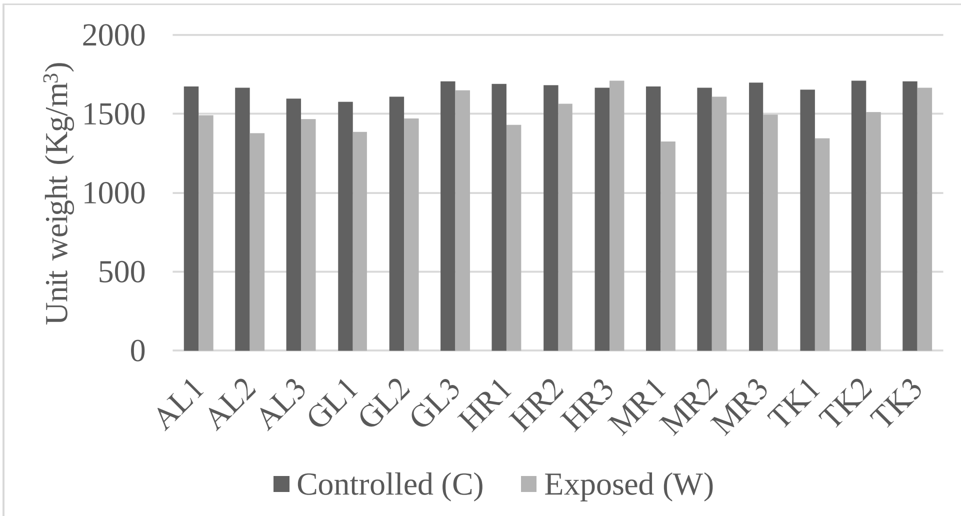
As shown in graph 4.18, the water flow of the sand source rivers has changed the total average bulking from 16.5% to 21.5%. In addition, the average bulking of exposed samples was above the average bulking of the controlled samples in all the five sand source rivers. It was clearly understood from the finding that, the presence of multi-size particles collected by the flow in a gap graded manner has its own effect on the bulking of sand samples.



Graph 4.18 bulking of controlled and exposed samples for water flow of the river basin

C. Unit weight and percentage void

The effect of water flow in the unit weight of sand samples as conducted based on the details of ASTM C 29 and C 128 was significant. As shown in graph 4.19, the unit weight of the exposed samples was 1500Kg/m^3 which is lower than that of the controlled samples unit weights which were 1665.5Kg/m^3.



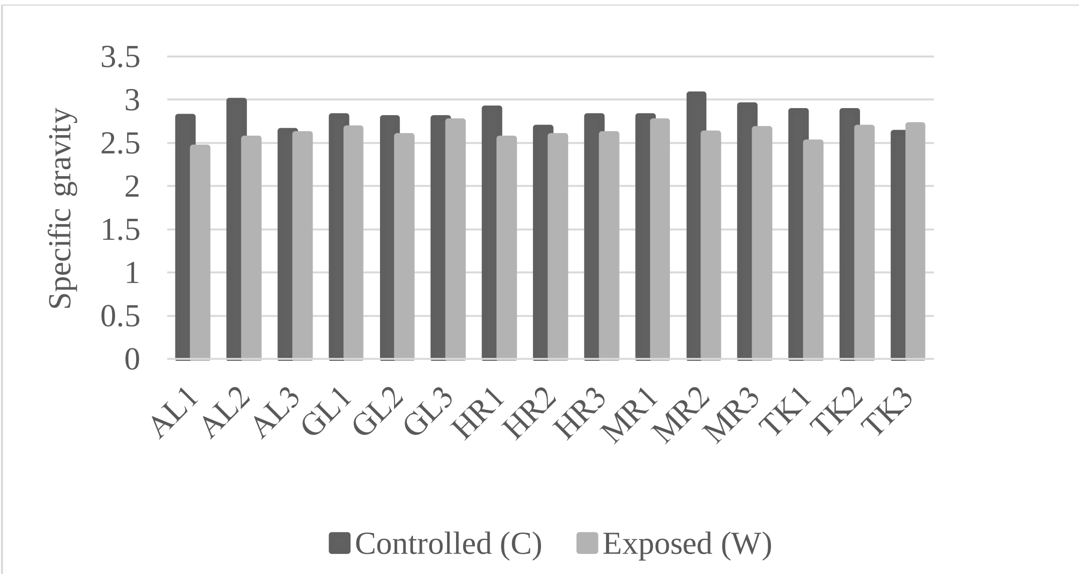
Graph 4.19 unit weight of controlled and exposed samples for water flow of the river basin

The average unit weight of all exposed samples was recorded below the minimum average unit weight value of the controlled samples; however, a few individual unit weight values of exposed samples were nearly equal to the top values of the controlled samples. It was clear that the unit weight of the samples was lowered by the small density materials which were accumulated by the flooding action. Though the laboratory result shows that the water flow of the river basin has the effect of reducing the unit weight of the samples, the numerical values of unit weight in both situations were within the recommended intervals for normal weight concrete which is 1200Kg/m^3-1750Kg/m^3.

The laboratory result conducted (as detailed in ASTM C1252) shows that the percentage void of the sand samples was changed by the water flow of the river basins in a total average of 5.5% (from 16.9% in a controlled situation to 22.5%. It could be understood by considering the difference in the unit weight of the samples that, the particle sizes of the exposed samples including different particles accumulated by the flooding of water was poorly distributed in comparison with the controlled samples.

D. Specific gravity

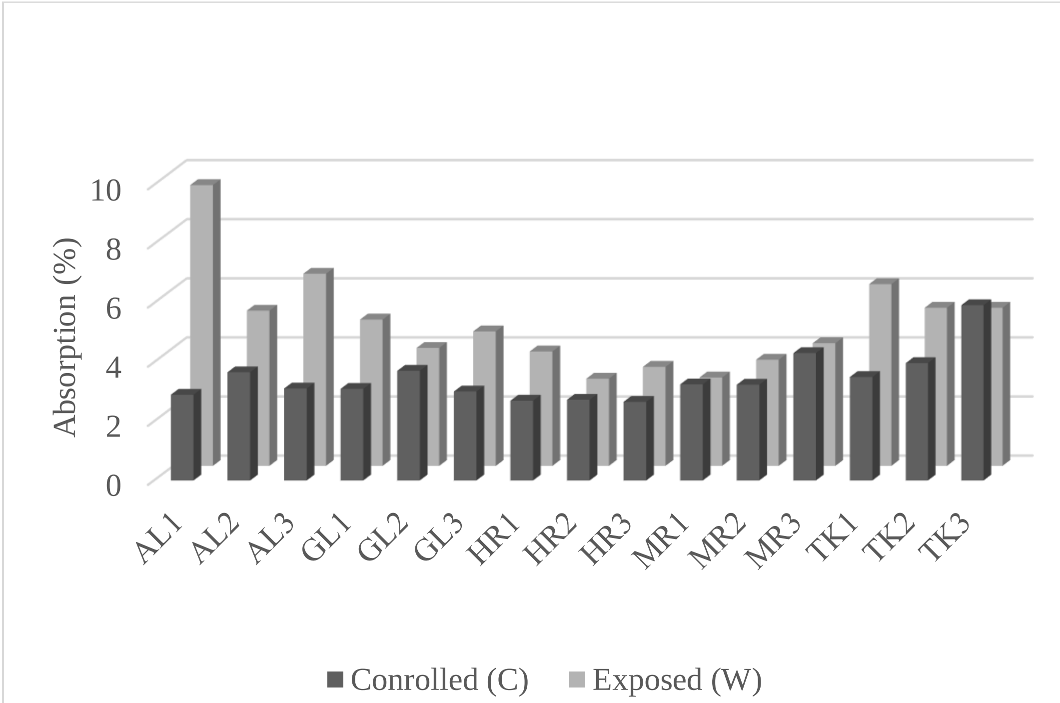
As shown in graph 4.20, the total average specific gravity of the exposed samples (2.62) as conducted detailed in ASTM C 128 was considerably affected in comparison with the controlled (2.83) samples with the difference of 0.21. The specific gravity of the individual exposed samples was between 2.45 to 2.75, while the controlled samples varied from 2.62 to 3.06. Most of the individual sand samples were within the recommended range which is 2.4-3.0, except the controlled single sample of MR2. It was understood that the miscellaneous particles added to the river sand by the actions of water flow has a lower density than the pure sand particles since their presence was lowered the specific gravity of exposed sand.



Graph 4.20 specific gravity of controlled and exposed samples for water flow of the river basin

E. Water absorption

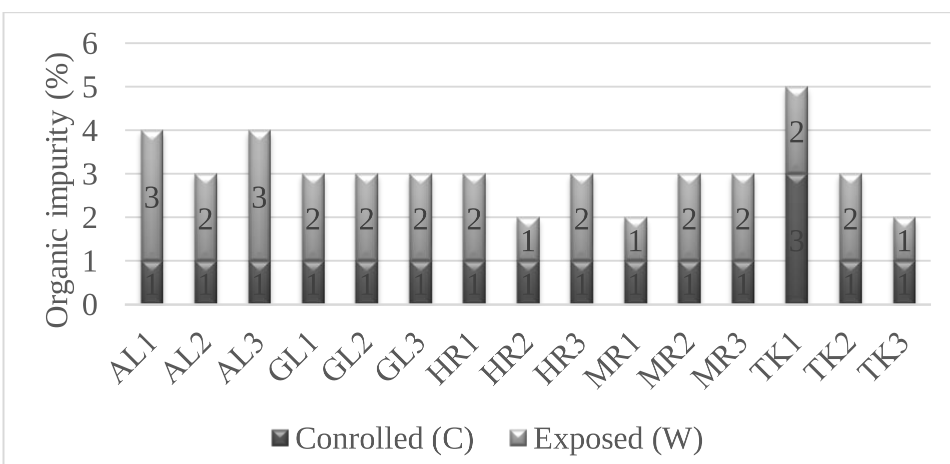
The laboratory conducted (detailed in ASTM C 128) shows that the particles added to the river by the actions of water flow had a significant effect in increasing the absorption of the exposed sand samples. As shown in graph 4.21, the total average absorption was changed from 3.45% in a controlled situation to 4.8 in an exposed situation, however, the absorption of Alawuha river samples in the exposure scenario was relatively higher. It could be understood that the particles added to the sand by the action of water flow had a relative higher absorption capacity.



Graph 4.21 water absorption of controlled and exposed samples for water flow of the river basin

F. Organic impurity

As shown in graph 4.22, the organic impurity of the sand samples was shown a slight variation between the exposed and controlled scenario. However the sand samples in both situation was within the recommended color indication which is below 3, the exposed samples had shown a number value above the controlled samples.

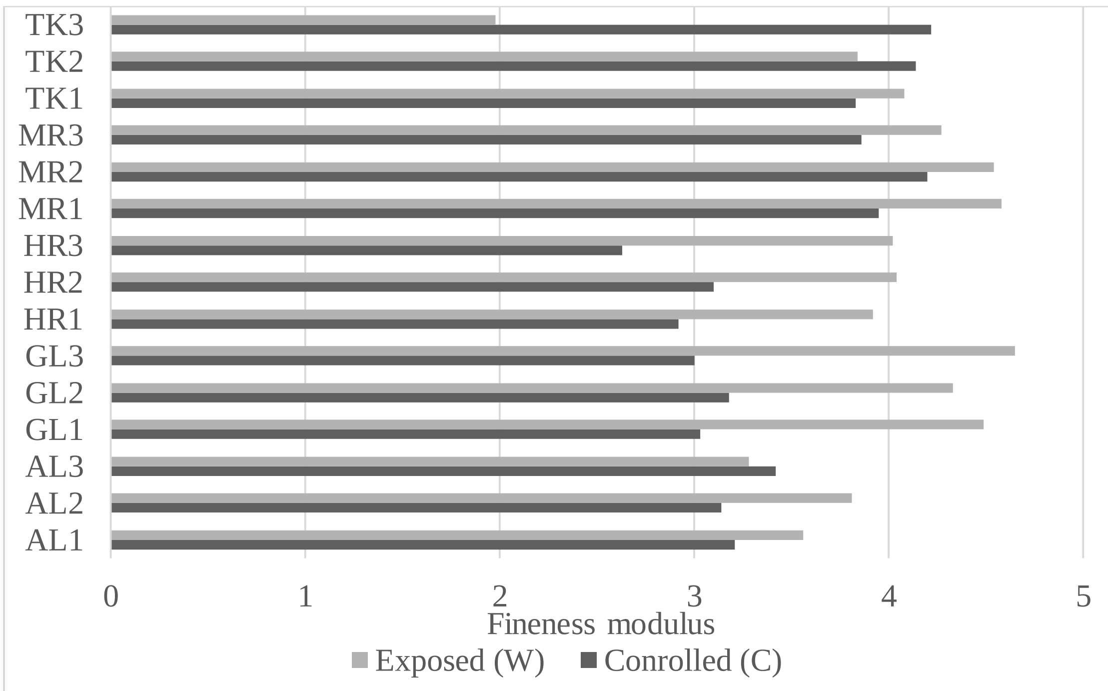


Graph 4.22 organic impurity of controlled and exposed samples for water flow of the river basin

G. Sieve analysis and fineness modulus

Fineness modulus

The total average fineness modulus of the exposed samples was calculated to be 3.96 which relatively higher than that of controlled samples (3.46). As shown in graph 4.23, most of the sand samples were recorded to be above the recommended value in the exposed condition except that of sample TK3, though the fineness modulus of the controlled samples also above the recommended limit for normal concrete which is from 2.3 to 3.1 in ASTM C 33.

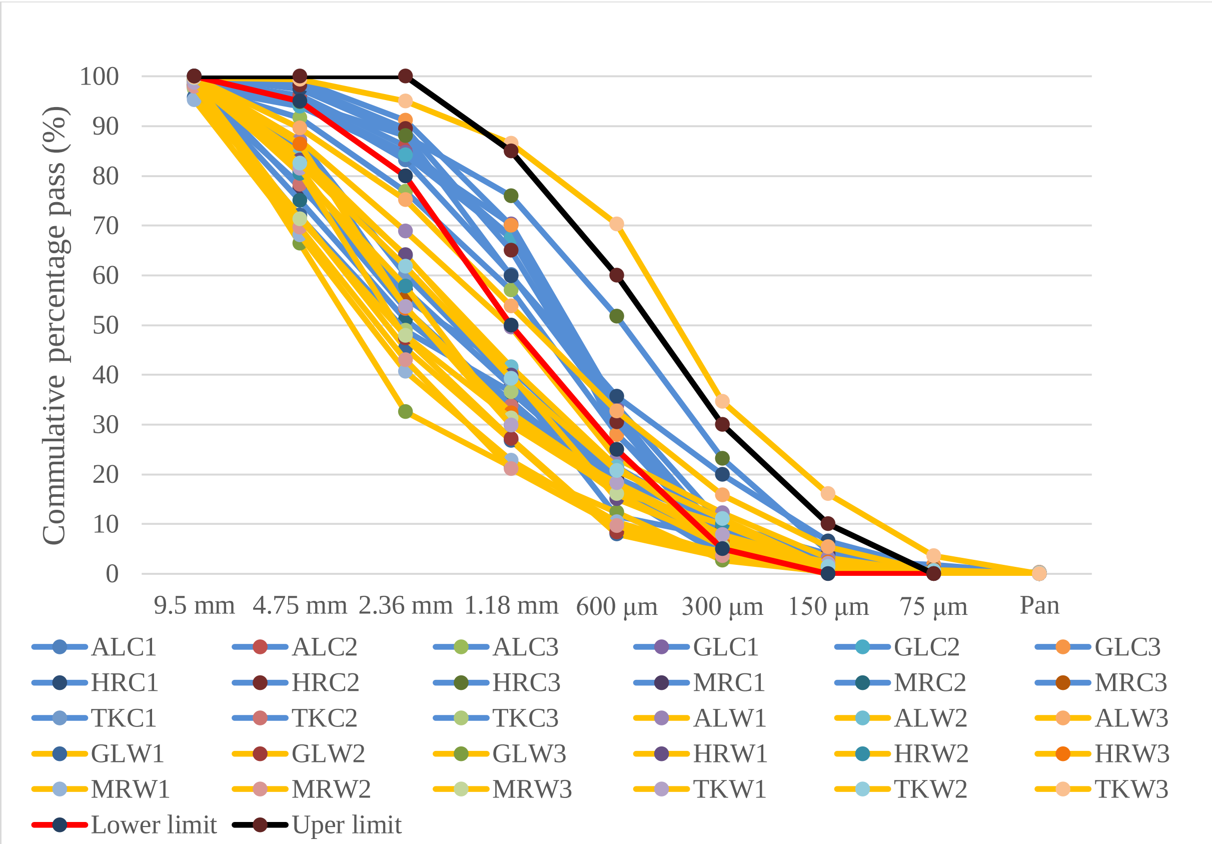


Graph 4.23 fineness modulus of controlled and exposed samples for water flow of the river basin

Even though most exposed samples were showing the higher fineness modulus relative to their corresponding controlled samples, a controlled sand samples of Mersa and Tikurwuha rivers were highly coarser. Considering that the silt content was relatively higher in exposed samples, it was clearly understood that the water flow was included different particles containing small as well as high sized particles.

Sieve analysis

As shown in graph 4.24, the cumulative percentage pass of the exposed samples was fall below the recommended lower limits of percentage pass in sieve sizes of above 300μm. as an exception, a sample TK3 was above the limit in the sieve sizes of the sieve below 2.36mm. In addition, the most exposed samples were containing some amount of sand in pan and 75μm sieve, on which a considerable amount of detainment is not allowed by ASTM C 33. Though some controlled samples failed below the lower limits in sieve sizes above 600μm, the difference was significantly visible that the exposed samples were highly retained in large size sieves than the controlled ones.



Graph 4.24 sieve analysis of controlled and exposed samples for water flow of the river basin

4.3.3.4. Soil, leaves and flora in the area

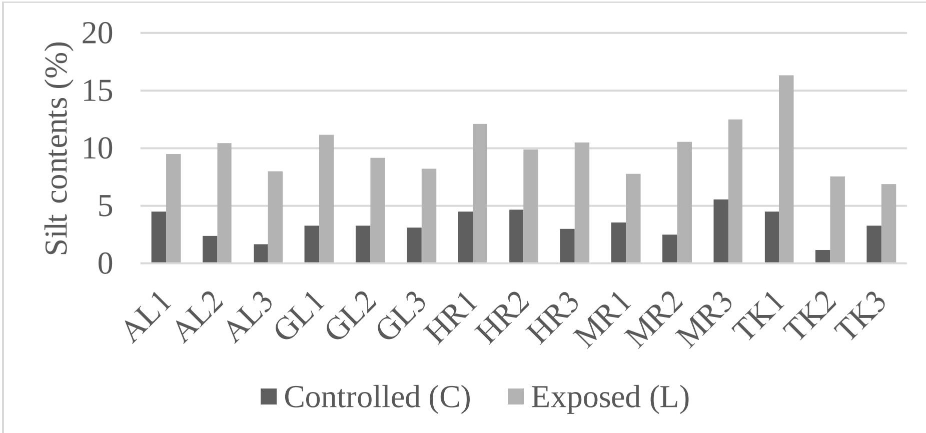
Introduction

These types of effects were mainly shown in the excavation of accumulated sand which was deposited and covered by topsoils and vegetables when the supplementary rivers flow deposits soil materials on the sand accumulation in the original river basin as shown in Figure 4.8. At the time when the accessible river sand has faced a shortage in the rivers, the accumulated sand would be needed to be excavated and produced for consumption. In this manner, the sand was consists of soils, leaves and flora deposits in the dry decay form. The sand produced was containing a higher amount of non-sand particles which has its own effect for uses of concrete production. For numerical test results of controlled samples and samples exposed to soil, leaves and flora action, see table 4.1 and 4.5. The effect of soil, leaves, and flora on the quality of river sand has discussed below.

Figure 4.8 sand Source Rivers with soil, leaves, and flora in the area

A. Silt content

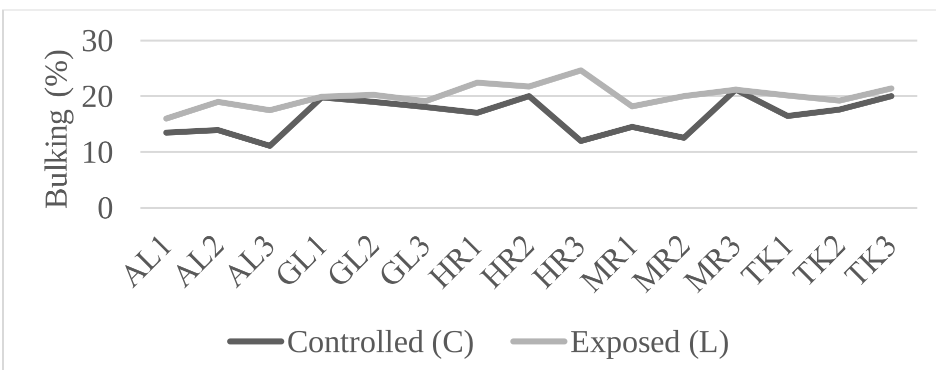
As shown in graph 4.25, the total average silt content of the controlled sand samples was recorded as 3.4% with the individual minimum silt content of 1.2% and maximum silt contents of 5.6%, while the exposed samples has the total average silt contents of 10% with minimum and maximum individual silt contents of 6.9% and 16.3% respectively. In exposed samples, 9.3% and 9.5% average silt content was observed in Alawuha and Golina river samples as a minimum value, while the other three river sand samples were recorded to have average silt contents between 10% to 11%. In a controlled situation, all samples had silt content below the allowable upper limits of the standard, while in an exposed situation all samples showed above the recommended limits of the Ethiopian standard, which is 6%. It was clear that the local soils, leaves, and flora has the effect of increasing the silt contents by mixed to the sand accumulation as the clay particles so that the sand which was exposed to Soil, leaves and flora action shall not be used for construction purpose except treatments have been done.



Graph 4.25 silt contents of controlled and exposed samples for soil, leaves, and flora

B. Bulking of sand

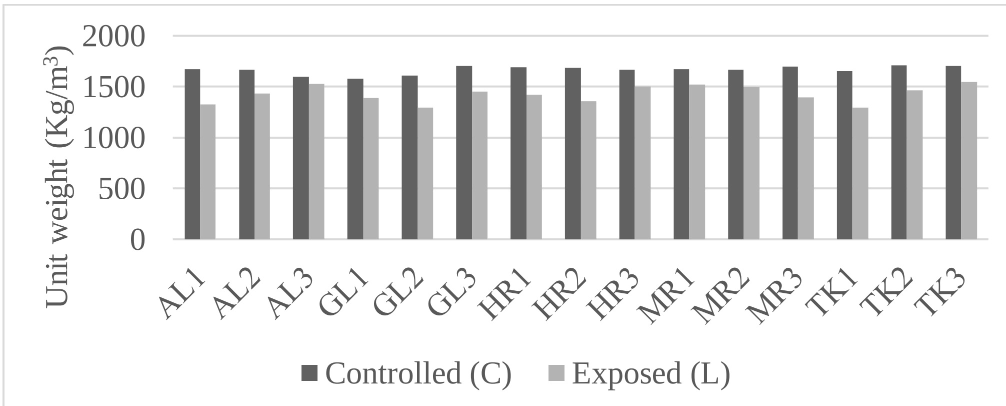
As shown in graph 4.26, the total average bulking of sand samples in an exposed situation was recorded as 20.1% with a minimum and maximum average value of 17.5% and 23% respectively, while in a controlled situation it was 16.5% with a minimum and maximum average value of 12.8% and 18.1% respectively. There was an ignorable variation that, the particles from Soil, leaves and flora action had increased the small particles which can be moved apart easily.



Graph 4.26 bulking of controlled and exposed samples for soil, leaves, and flora

C. Unit weight and percentage void

The unit weight of sand samples in an exposed situation was examined based on ASTM C 29 and C 128.It was significantly affected by the soil, leaves and flora action, numerically varied from 1665.3Kg/m^3 in a controlled situation to 1429Kg/m^3. As shown in graph 4.27, the unit weight of the exposed samples has a minimum and maximum average values of 1380Kg/m^3 and 1472.2Kg/m^3 in Golina and Mersa River respectively. However, the average unit weight of the controlled samples was recorded to be between 1632Kg/m^3 and 1690Kg/m^3. It was shown that the particles added to the sand from soil, leaves and flora action had the unit weight lower than that of the normal sand particles. Though there was a significant variation in the two scenarios which clearly show the effect of soil, leaves and flora action, the unit weight of both scenarios was within the recommended interval for the normal weight concrete, which is 1200Kg/m^3-1750Kg/m^3.

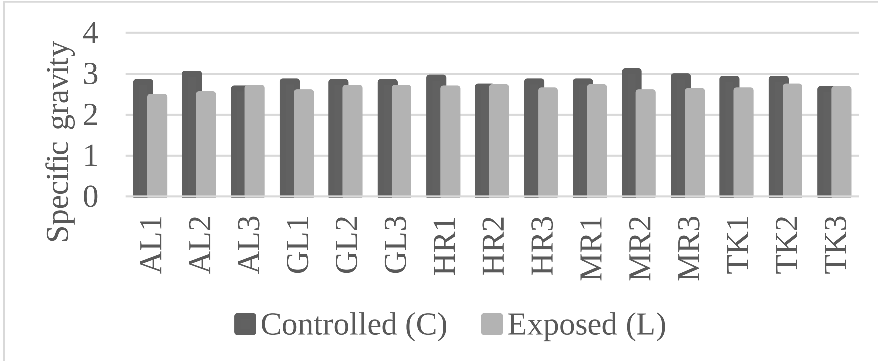


Graph 4.27 unit weight of controlled and exposed samples for soil, leaves, and flora

The total average percentage void (based on ASTM C1252) in the exposed samples (16.4) did not show a significant difference from the controlled samples (16.9), though the range was 10.1-23% in controlled sand samples and 12.9-19.5% in exposed sand samples. Remembering the significant variation in the unit weight, it could be understood that the relatively good grading of exposed samples played a significant role to reduce the range of the void values than the void value of controlled samples.

D. Specific gravity

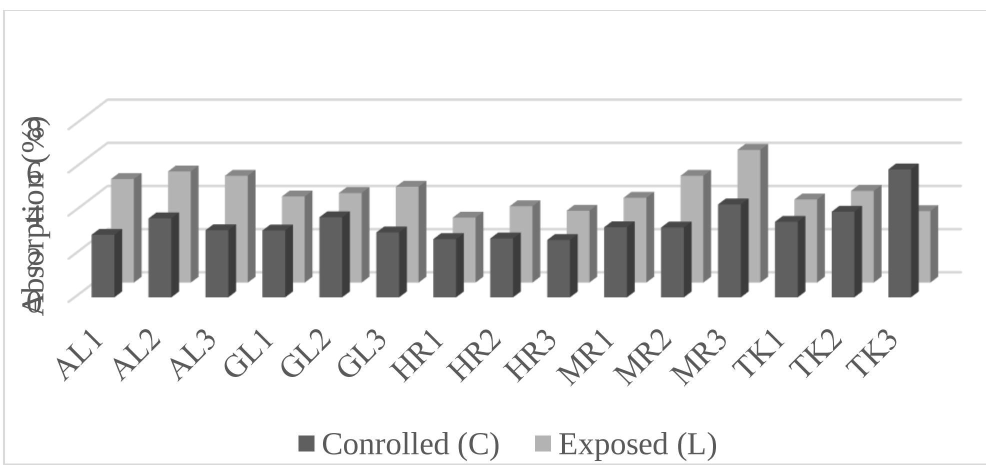
As shown in graph 4.28, the presence of soil, leaves, and flora in the area had shown a significant effect on the specific gravity of the river sand samples. The laboratory (as detailed in ASTM C 128) results show that the total average specific gravity of the exposed samples (2.6) was lower than that of the controlled samples (2.83). The average minimum and maximum specific gravity values of exposed situations were 2.53 and 2.63 in Alawuha, and Hormat and Tikurwuha river sand samples respectively. While the average minimum and maximum values in a controlled situation were 2.79 and 2.94 in Tikurwuha and Mersa river sand samples respectively, though most values have obtained to be ≈2.79.



Graph 4.28 specific gravity of controlled and exposed samples for soil, leaves, and flora

E. Water absorption

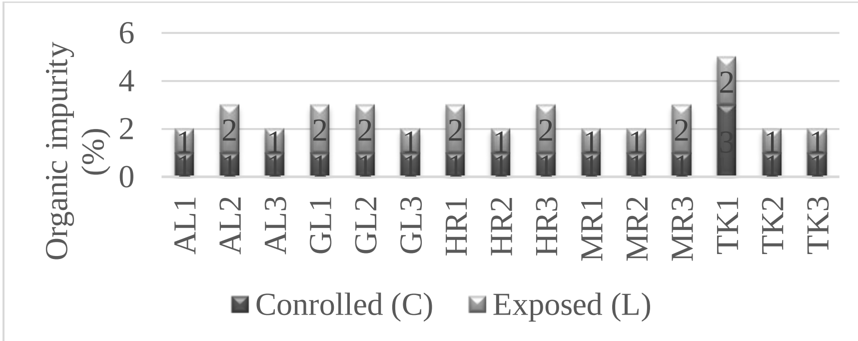
As shown in graph 4.29, the total average water absorption of the exposed samples (4.3%) was significantly affected by the presence of soil, leaves, and flora, in comparison to the controlled sand samples (3.45%). In an exposed scenario, the minimum and maximum average values of water absorption was recorded as 3.3% and 5% in Hormat and Mersa River respectively, however, the individual values in the exposure scenario were as high as 6.2%. It could be because of the high water absorption capacity of extra particles added to the sand due to the considered factor.



Graph 4.29 water absorption of controlled and exposed samples for soil, leaves, and flora

F. Organic impurity

As the test results in graph 4.30 show, the presence of soil, leaves, and flora in the sand production area had slightly varied the organic impurity values in some sand samples of exposure scenarios. Organic impurity value in both situations was within the recommended values of ASTM C 40 in which it was acceptable for concrete production.

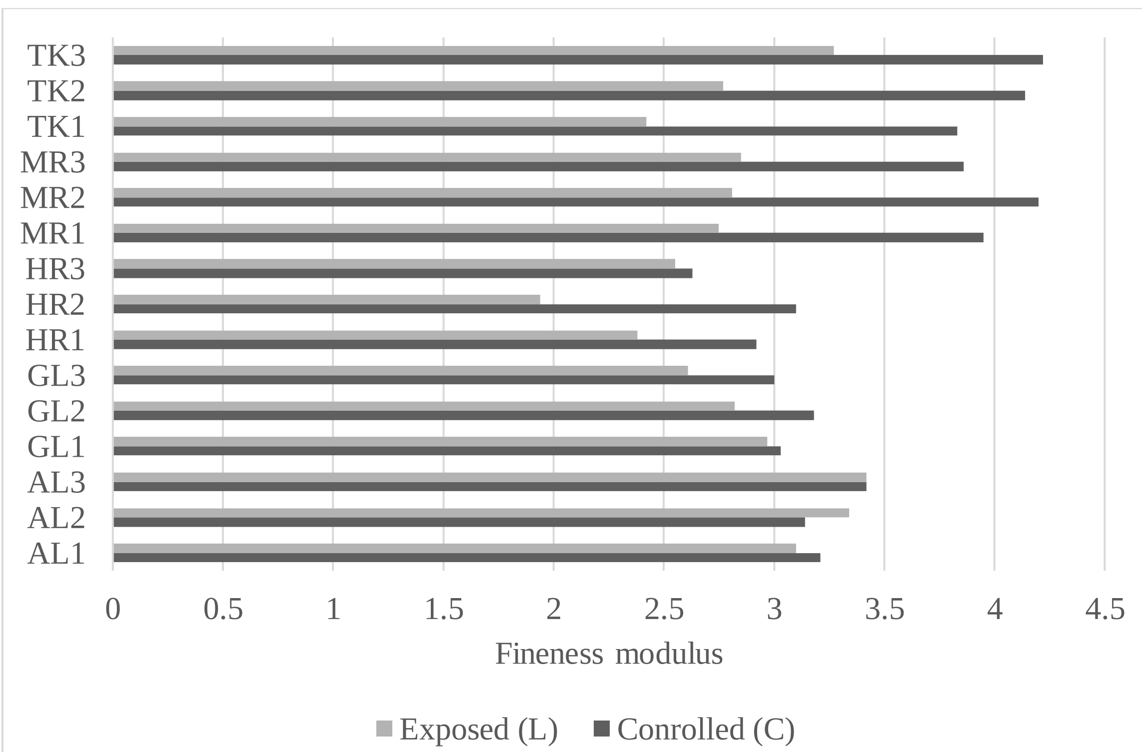


Graph 4.30 organic impurity of controlled and exposed samples for soil, leaves, and flora

G. Sieve analysis and fineness modulus

Fineness modulus

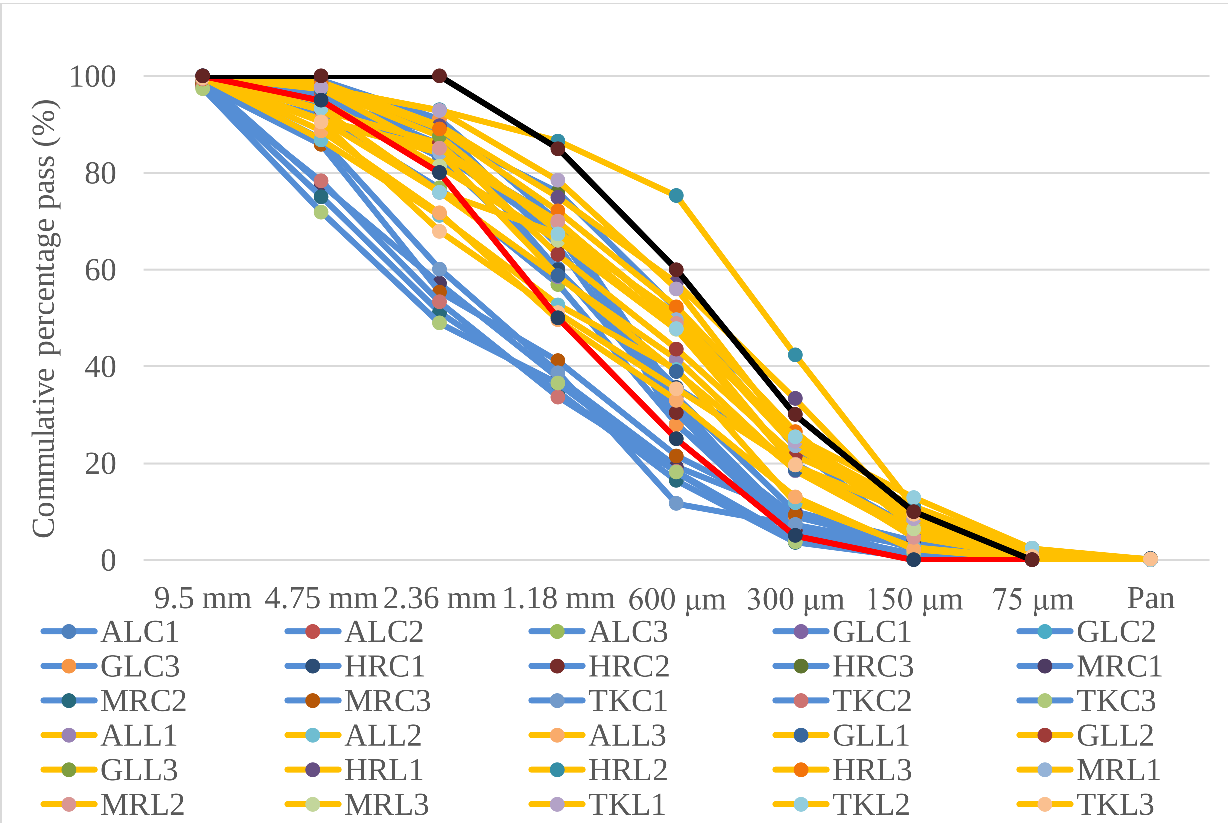
As shown in graph 4.31, the total average fineness modulus was 2.8 in exposed sand samples, which was affected by the presence of small particles sourced from the presence of soil, leaves, and flora. Though it has fineness modulus value within the ranges of ASTM C 33 which is between 2.3 and 3.1 for a normal property concrete, the added particles have its own effect in silt content, unit weight and organic impurity of sand. In a controlled situation, the fineness modulus of the sand samples (3.5) was above the limit of ASTM C 33.



Graph 4.31 fineness modulus of controlled and exposed samples for soil, leaves, and flora

Sieve analysis

As shown in graph 4.32, the particle size distribution of the most exposed river sand samples were within the recommended lower and upper limits of ASTM C 33 in the sieve sizes between 150µm and 2.36mm, while most of the controlled sand samples have fall below the recommended commutative percentage pass in the sieve sizes above 300µm. it was clearly understood that the controlled samples have coarser sand particles while the exposed samples contain smaller particles due to the presence of soil, leaves, and flora in the area.

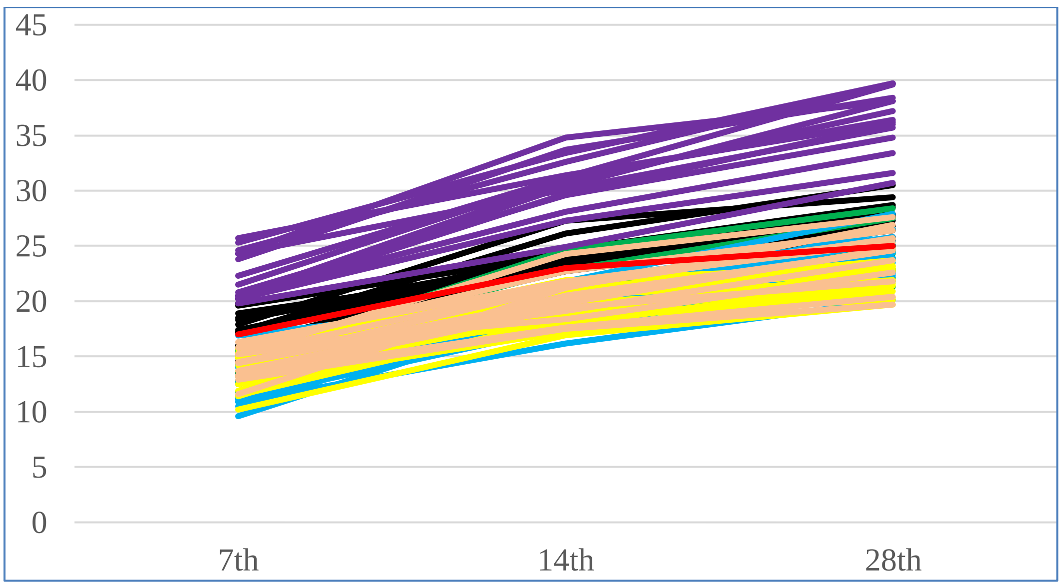


Graph 4.32 sieve analysis of controlled and exposed samples for soil, leaves, and flora

4.3.4. Compressive strength of concrete

As shown in graph 4.33, humans, animals and truck action was reduced the average compressive strength of concrete from 27.4MPa to 24MPa by the presence of small-sized sand particles in the exposed condition. The controlled sand has produced concrete with more than the expected 28th-day compressive strength which is 25MPa, while the exposed samples of sand have produced concrete with a compressive strength of less than the expected values in all days of measurement.

Detergent and sewage action was affecting the compressive strength of concrete in the exposure scenario. The average compressive strength of exposed samples in 14th (19MPa) and 28th (21MPa) days of measurement was showing a decline relative to the controlled situations, the reason may be the presence of considerable organic impurities. The specimen compressive strength was lower than the expected strength of the C25 concrete in all days of measurement. Compressive strength of concrete produced using exposed sand samples exposed to water flow and soil, leaves and flora were 24.3MPa which was lower than the strength of concrete specimen produced from the controlled sand samples.



Legend

- Controlled sand samples
- Sand samples exposed to human, animals, and truck action
- Sand samples exposed to detergent and sewage action
- Sand samples exposed to water flow of the river basins
- Sand samples exposed to soils, leaves, and flora
- Sand samples exposed to production treatment and storage
- Expected compressive strength values

Graph 4.33 compressive strength of sand samples exposed by different factors

The sand samples which were washed, treated and distributed sand particles in an ideal average manner have shown a considerable difference in compressive strength in all days of measurements. Though the controlled (normal) sand samples had able to produce concrete with compressive strength greater than the expected values, it was not guaranteed for practical use since attaining the ideal value is challenging in the mass production of concrete. The sand within the production treatment and storage action has a compressive strength of 22.3MPa, 30.6MPa, and 36.4MPa for the 7th, 14th and 28th days of measurements, which is significantly greater than the controlled sand samples with compressive strength of 17MPa, 23.6MPa and 27.5MPa.

4.3.5. Standardization (production, treatment, and storage) of river sand

4.3.5.1. Introduction

The production, treatment and storage effect on the sand samples was done by; washing the normal samples to make silt and organic impurities ignorable, take the washed sand samples with the predetermined particles distribution and fineness modulus, and keeping the prepared sample in the controlled condition until the samples have been tested. In all sand samples, the production of standardized sand was done by the ideal average percentage pass with 2.8 fineness modulus. As the laboratory result shows, the production treatment and storage had a significant role in obtaining sand with ignorable silt content (≈0%) and organic impurities (1 in color test value). The unit weight and specific gravity of the treated and well-stored sand were higher relative to controlled (normal) and exposed samples, because of that the unnecessary lower density particles could be removed at the time of treating. In the production of standardized sand, the particle size distribution and fineness modulus can be marked up in the needs of the consumer. For numerical test results of controlled samples and samples exposed to production, storage and treatment, see table 4.1 and 4.6.

4.3.5.2. Production of standardized river sand

Standardization can be applied in the mass production of the river sand as the production treatment and storage effect which has been used for the experimental purpose in this research. In mass production, some sizes of sand can be available in the limited amount to produce the required amount of sand with specific grading and fineness modulus, however, the coarser sand can roughly be crushed to make the required lower particle sizes available. As shown in the production treatment and storage effect, the production of standardized river sand could have the following advantages over the traditional production system.

- In mass production, the machinery based nature of standardization can advance the machine technology for the workers and helps the construction industry.
- The standardized sand can be produced based on the predetermined parameters of sand property so that the needs of the consumer can be considered.
- Job opportunities for sand production can play a role in minimizing the increasing numbers of unemployment in the country.
- Standardization of river sand helps in the proper usage of scarce natural resources.
- Standardization could have the role of supplying a consistent and brand product depend on the needs of the consumer.

In the Ethiopian construction industry, the river sand production system was undergoing traditionally by the labors with no treatment methods has been applied. It is not satisfactory for the growing demands of the construction industry by which both urban and rural community of the country needs to have an infrastructural and technological access. Bearing in mind the increasing demand for sand in developing infrastructure needs of the society and the decreasing production capacity of the rivers, the future will be difficult in the non-existence of standardized production and proper usage of natural river sand. In order to overcome the demand for construction industries with the natural sand, the mass production of river sand should be managed and shaped in the production of consistent and standardized sand. So that the production technology of sand and aggregate in general, should be performed in a machinery based manner. The machinery based sand production and treatment systems can overcome most problems associated with the traditional ways of production. In addition to obtaining the consistence quality sand for the construction industry, producing the standardized sand has its own advantage in different parameters of production and usage effectiveness of concrete ingredients.

4.3.5.3. Evaluation of standardized river sand production

As the consumers of river sand tells that, there was no standardized river sand in the market, legal branded products has not adopted for the natural materials; even no grade of sand and aggregate qualities except the size designations of coarse aggregates as 00, 01, 02, 03 and 04, however, crushed aggregate with designation of ‘00” mostly used as a manufactured fine aggregate.

In the usages of natural sand, the practices of washing and removing unnecessary particles at the site level were consuming additional materials (probably additional water trucks) human resources and higher treatment time which further affect the setting and consistencies of concrete and time plan of the corresponding activities. Since the particle size higher and lower than the recommended upper and lower limits have to be removed, the initial demand for sand and the wastages in the treatment process would be increased. The supplying chains of the river sand were mostly done by illegal brokers in an inauthentic manner so that it was difficult to order and accept the product within the acceptable quality, required quantity, reasonable cost and at the required time.

In the laboratory tests for the sand samples which was prepared in the situations of good production treatment and storage mechanisms, it was clear that there were expending relatively higher cost for the processing of non-standardized river sand samples. In the requirements of the constant amount of sand product, there were clearly shown the increase in the consumption of river sand which further reduced the screening process, washing and the process of making the required size distributions. Since the process could take the applications of different processes and machinery, it was also true in the mass standardization of river sand to increase the cost of final processed product in comparison to the roughly produced sand products.

The river sand has a difficulty of unknown characteristics which varies through each sample since the sand particles were produced in the uncontrolled conditions. In the absence of predetermined sand characteristics and inconsistent properties within the mass supplies, mix design of concrete would be unthinkable even though the characteristics of other ingredients were well known. In most cases, it was difficult to store a considerable amount of sand because of the unavailability of the places in the construction sites, while repetitive ordering has a difficulty of dubiety for the availability of sand in the market at the ordering time which further affect the progress of the project. In general, the unprocessed sand has a higher cost of rework for the low quality completed physical works, relatively higher wastages, negotiating the quality of concrete structures and other controversies with the clients.

5. Conclusion and recommendation

5.1. Conclusion

- It was shown from the research finding that, the production process and quality of river sand was considerably affected by agricultural activities, wastage removals, and recreational activities around the river basins.
- It was clearly observed from the laboratory results that, the human, animals and truck action have significant negative effect on the silt content, bulking, unit weight, specific gravity, absorption capacity, fineness, and particle size distributions of sand. While the effect on the organic impurities was not significant.
- It was understood from the research findings that, the detergent and sewage in the rivers affected the silt contents, organic impurities, and specific gravities. While the bulking, unit weight and water absorption capacity were not significantly affected.
- It was shown in the research results that, the higher amount of water flow containing non-sandy materials significantly affected the silt content, bulking, unit weight, specific gravity, and water absorption. While the effect on the distributions of sand particles was non-linear.
- The presence of soil, leaves and flora accumulations significantly affected the silt content, unit weight, specific gravity, water absorption and specifically fineness modulus of sand.
- The river sand exposed to different factors in the same river exhibited considerable fluctuation in the properties of the sand, so that it was difficult to design a concrete mix with confidence of having consistent river sand quality.
- It was shown in the laboratory results that, the exposed sand showed compressive strength lower than expected, while the standardized sand showed higher compressive strength at all ages.
- It was understood from the research that, washing the river sand to make silt and organic impurities ignorable, adjusting the sand particles in the required predetermined distribution, and keeping the product in the controlled condition was recommended treatment methods.

5.2. Recommendation

Based on the research findings, the following recommendations were drawn-out.

- Agricultural and water usage practices of the community should be controlled by the respective bodies to be undergone in the best ways with no effect on the wellbeing of sand production and the effectiveness of the agricultural processes.
- The sand source river basins should be kept free from the interaction of uncontrolled human, animals and truck action by which the river sand particles were broken-down and the non-sandy substances were disturbed and mixed with the sand accumulations.
- The dirt particles and sewages of the town should not be mixed with the sand source rivers for the purpose of producing river sand free from the impurities.
- The river sand production should not be done in the presence of high river water flow since the flooding contains non-sand substances and the river water flow makes the sand production process difficult.
- The river sand which was deposited in the basins and covered by the soils and leaves should not be directly excavated and used from the accumulation area since the sand deposit could contain flora decades and soils.
- The sand production process should be undergone in the modern methods on which the process should not affect the quality and consistency of the product.
- The sand source rivers should be managed by the regulatory bodies for the quality of sand in the construction industry and the environment on which the agricultural practices of the community depends.
- Supplying a standardized and consistent sand product with a given brand should be adopted in the construction industry so that the consumers buy the required amount of branded sand.
- Since the properties of sand sourced from different rivers and parent rocks would not be similar, there should be a grade designation of the river sand based on the quality and levels of achieving the required strength of concrete products.
- All stakeholders in the construction and mining industry should be responsible for the protection of sand source rivers and the environs. The government should ensure the applicability of sand mining and environmental protection reclamations.

5.3. Suggestion for future works

- Assessment of the possible designations for the standardized river sand grades.
- The importance of sand supply consistency and designation on the construction industry.
- Assessment of the contributions of the specific sand properties on the grade designation of the standardized river sand.
- Feasibility study of machinery based river sand production in the potential sand source rivers.
- Designing the modern production system model for the usage of river sand in a sustainable environment.
- Expressive formula for the effect of sand grade on compressive strength of concrete.

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Appendix

Appendix 1: Checklists for the interview and field test considerations

No.	Checklists
1	Social practices around the rivers
2	Land use in the river area
3	River sand production and treatments
4	About producers; group members and their academic level, license of producers
5	Production system, machinery
6	Place of river sand production points
7	The major users of the river sand in the area
8	Consumer choice, and their comments on river sand and parameters of selection
9	The factors to change the current quarry site
10	Effect sand on-site works effectiveness and wastage of ingredients
11	Transport mechanisms of river sand to the consumers
12	What, how where are the factors that degradation on the quality of sand
13	Environmental aspects
14	Consideration of sample taking for the laboratory tests

Appendix 2: Laboratory test results of Alawuha River Sand
1.1.Experimental Result of Alawuha controlled samples (ALC)
Part 1.
River quarry: AL Supply point (code): ALC points

No.	Supply points (by code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALC_1	Silt content	%	4.5	Jar test
		Bulking of sand	%	13.5	Jar test
		Unit weight	Kg/m^3	1672.5	Loose method
		Percentage void	%	16.8	Effect of compaction
		Specific gravity	-	2.8	ACI
		Absorption	%	2.9	ACI
		Organic impurity	Number	1	Color chart
2	ALC_2	Silt content	%	2.35	Jar test
		Bulking of sand	%	13.89	Jar test
		Unit weight	Kg/m^3	1664.5	Loose method
		Percentage void	%	17.45	Effect of compaction
		Specific gravity	-	2.99	ACI
		Absorption	%	3.66	ACI
		Organic impurity	Number	1	Color chart
3	ALC_3	Silt content	%	1.66	Jar test
		Bulking of sand	%	11.11	Jar test
		Unit weight	Kg/m^3	1595.8	Loose method
		Percentage void	%	22.95	Effect of compaction
		Specific gravity	-	2.64	ACI
		Absorption	%	3.11	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength
⇨ Alawuha River Controlled sample (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	18.2	ACI mix design method for C-25
14^{th}	25.9	ACI mix design method for C-25
28^{th}	29	ACI mix design method for C-25

Part 3. Sieve Analysis
⇨ Alawuha River Controlled sample 1 (ALC_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.8	0.16	0.16	99.84	100	100
4.75 mm	21.42	4.28	4.44	95.56	95	100
2.36 mm	61.8	12.36	16.8	83.2	80	100
1.18 mm	115.09	23.02	39.82	60.18	50	85
600 µm	141.57	28.31	68.13	31.87	25	60
300 µm	122.98	24.6	92.73	7.27	5	30
150 µm	31.85	6.37	99.1	0.9	0	10
75 µm	3.55	0.71	99.81	0.19	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 3.21

⇨ Alawuha River Controlled sample 2 (ALC_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	3.75	0.75	0.75	99.25	100	100
4.75 mm	15.4	3.08	3.83	96.17	95	100
2.36 mm	50.8	10.17	14	86	80	100
1.18 mm	96.5	19.3	33.3	67.7	50	85
600 µm	169.8	33.96	67.26	32.74	25	60
300 µm	136.7	27.34	94.6	5.4	5	30
150 µm	26.1	5.22	99.82	0.18	0	10
75 µm	0.8	0.16	99.98	0.02	0	0
Pan	0	0	0	0		
Total			411.46			

Fineness Modulus of fine aggregate = 3.14

⇨ Alawuha River Controlled sample 3 (ALC_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	9.35	1.87	1.87	98.13	100	100
4.75 mm	32.05	6.41	8.28	91.72	95	100
2.36 mm	74.3	14.86	23.14	76.86	80	100
1.18 mm	99.5	19.9	43.03	56.97	50	85
600 µm	144.2	28.84	71.88	28.12	25	60
300 µm	114.6	22.92	94.8	5.2	5	30
150 µm	22.9	4.58	99.38	0.62	0	10
75 µm	1.1	0.22	99.6	0.4	0	0
Pan						
Total						

Fineness Modulus of fine aggregate = 3.42

1.2.Experimental Result of samples affected by human and animal (ALH)
Part 1.
River quarry: AL Supply point (code) ALH points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALH_1	Silt content	%	15	Jar test
		Bulking of sand	%	18.5	Jar test
		Unit weight	Kg/m^3	1499.5	Loose method
		Percentage void	%	25.35	Effect of compaction
		Specific gravity	-	2.62	ACI
		Absorption	%	4.5	ACI
		Organic impurity	Number	2	Color chart
2	ALH_2	Silt content	%	9	Jar test
		Bulking of sand	%	21.5	Jar test
		Unit weight	Kg/m^3	1582.6	Loose method
		Percentage void	%	19.85	Effect of compaction
		Specific gravity	-	2.65	ACI
		Absorption	%	4.0	ACI
		Organic impurity	Number	1	Color chart
3	ALH_3	Silt content	%	11	Jar test
		Bulking of sand	%	17	Jar test
		Unit weight	Kg/m^3	1579.45	Loose method
		Percentage void	%	21.3	Effect of compaction
		Specific gravity	-	2.6	ACI
		Absorption	%	7	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength
⇨ Alawuha River samples affected by human and animal (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7th	12.3	ACI mix design method for C-25
14th	20.38	ACI mix design method for C-25
28th	25.64	ACI mix design method for C-25

Part 3. Sieve Analysis
⇨ Alawuha River samples affected by human and animal 1 (ALH_1)
Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	5.96	1.19	1.19	98.81	80	100
1.18 mm	87.25	17.45	18.64	81.36	50	85
600 µm	137.28	27.46	46.1	53.9	25	60
300 µm	142.51	28.5	74.6	25.4	5	30
150 µm	81.68	16.34	90.94	9.06	0	10
75 µm	32.84	6.57	97.51	2.49	0	0
Pan	11.95	2.39	99.9	0.1		
Total						

Fineness Modulus of fine aggregate = 2.32

⇨ Alawuha River samples affected by human and animal 2 (ALH_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0.5	0.1	0.1	99.9	95	100
2.36 mm	27.5	5.5	5.6	94.4	80	100
1.18 mm	166.5	33.3	38.9	61.1	50	85
600 µm	99.8	19.96	58.86	41.14	25	60
300 µm	106.7	21.34	80.2	19.8	5	30
150 µm	67.1	13.42	93.62	6.38	0	10
75 µm	29.6	5.92	99.54	0.46	0	0
Pan	2	0.4	99.94	0.06		
Total						

Fineness Modulus of fine aggregate = 2.77

⇨ Alawuha River samples affected by human and animal 3 (ALH_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	30.25	6.05	6.05	93.95	80	100
1.18 mm	169.65	33.93	39.98	60.02	50	85
600 µm	98.7	19.74	59.72	40.28	25	60
300 µm	105.25	21.05	80.77	19.23	5	30
150 µm	47.76	9.55	90.32	9.68	0	10
75 µm	38.91	7.78	98.1	1.9	0	0
Pan	9.11	1.83	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 2.76

1.3.Experimental Result samples affected by detergent and sewage (ALD)
Part 1.
River quarry: AL Supply point (code): ALD

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALD_1	Silt content	%	11.5	Jar test
		Bulking of sand	%	22	Jar test
		Unit weight	Kg/m^3	1309.03	Loose method
		Percentage void	%	16.89	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	7.5	ACI
		Organic impurity	Number	3	Color chart
2	ALD_2	Silt content	%	9.5	Jar test
		Bulking of sand	%	18	Jar test
		Unit weight	Kg/m^3	1528.63	Loose method
		Percentage void	%	20.75	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	8	ACI
		Organic impurity	Number	4	Color chart
3	ALD_3	Silt content	%	11.5	Jar test
		Bulking of sand	%	19	Jar test
		Unit weight	Kg/m^3	1456.25	Loose method
		Percentage void	%	18.78	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	4.96	ACI
		Organic impurity	Number	3	Color chart

Part 2. Concrete compressive strength

⇨ Alawuha River samples affected by detergent and sewage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	12.3	ACI mix design method for C-25
14^{th}	18.4	ACI mix design method for C-25
28^{th}	20.7	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Alawuha River samples affected by detergent and sewage 1 (ALD_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.14	0.23	0.23	99.77	100	100
4.75 mm	9.72	1.94	2.17	97.83	95	100
2.36 mm	54.8	10.96	13.13	86.87	80	100
1.18 mm	110.05	22.01	35.14	64.86	50	85
600 µm	168.52	33.7	68.84	31.16	25	60
300 µm	89.74	17.95	86.79	13.21	5	30
150 µm	47.94	9.59	96.38	3.62	0	10
75 µm	15.72	3.14	99.52	0.48	0	0
Pan	1.97	0.39	99.91	0.09		
Total						

Fineness Modulus of fine aggregate = 3.03

⇨ Alawuha River samples affected by detergent and sewage 2 (ALD_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.95	0.39	0.39	99.61	100	100
4.75 mm	8.58	1.72	2.11	97.89	95	100
2.36 mm	48.57	9.72	11.83	88.17	80	100
1.18 mm	114.85	22.97	34.8	65.2	50	85
600 µm	173.64	34.73	69.53	30.47	25	60
300 µm	91.76	18.35	87.87	12.13	5	30
150 µm	51.09	10.22	98.09	1.91	0	10
75 µm	9.47	1.89	99.98	0.02	0	0
Pan	0					
Total						

Fineness Modulus of fine aggregate = 3.05

⇨ Alawuha River samples affected by detergent and sewage 3 (ALD_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.85	0.57	0.57	99.43	100	100
4.75 mm	9.51	1.9	2.47	97.53	95	100
2.36 mm	38.94	7.79	10.26	89.74	80	100
1.18 mm	135.46	27.09	37.35	62.65	50	85
600 µm	100.15	20.03	57.38	42.62	25	60
300 µm	129.61	25.92	83.3	16.7	5	30
150 µm	78.43	15.69	98.99	1.01	0	10
75 µm	3.25	0.65	99.64	0.36	0	0
Pan	0.57	0.11	99.75	0.25		
Total						

Fineness Modulus of fine aggregate = 2.90

1.4.Experimental Result of samples affected by water flow of the river (ALW)
Part 1.
River quarry: AL Supply point (code): ALW points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALW_1	Silt content	%	14.5	Jar test
		Bulking of sand	%	21	Jar test
		Unit weight	Kg/m^3	1489.75	Loose method
		Percentage void	%	31.28	Effect of compaction
		Specific gravity	-	2.45	ACI
		Absorption	%	9.5	ACI
		Organic impurity	Number	3	Color chart
2	ALW_2	Silt content	%	11.5	Jar test
		Bulking of sand	%	18	Jar test
		Unit weight	Kg/m^3	1378.54	Loose method
		Percentage void	%	28.13	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	5.25	ACI
		Organic impurity	Number	2	Color chart
3	ALW_3	Silt content	%	14.5	Jar test
		Bulking of sand	%	21	Jar test
		Unit weight	Kg/m^3	1467.24	Loose method
		Percentage void	%	22.15	Effect of compaction
		Specific gravity	-	2.6	ACI
		Absorption	%	6.5	ACI
		Organic impurity	Number	3	Color chart

Part 2. Concrete compressive strength

⇨ Alawuha River samples affected by water flow of the river (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13.3	ACI mix design method for C-25
14^{th}	21.6	ACI mix design method for C-25
28^{th}	25.4	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Alawuha River samples affected by water flow of the river 1 (ALW_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.24	0.25	0.25	99.75	100	100
4.75 mm	62.81	12.56	12.81	87.19	95	100
2.36 mm	91.81	18.36	31.17	68.83	80	100
1.18 mm	96.24	19.25	50.42	49.58	50	85
600 µm	132.36	26.47	76.89	23.11	25	60
300 µm	54.21	10.84	87.73	12.27	5	30
150 µm	45.16	9.03	96.76	3.24	0	10
75 µm	15.09	3.02	99.78	0.22	0	0
Pan	0.75	0.15	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 3.56

⇨ Alawuha River samples affected by water flow of the river 2 (ALW_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	3.58	0.72	0.72	99.28	100	100
4.75 mm	74.46	14.89	15.61	84.39	95	100
2.36 mm	102.64	20.53	36.14	63.86	80	100
1.18 mm	111.23	22.25	58.39	41.61	50	85
600 µm	100.47	20.09	78.48	21.52	25	60
300 µm	71.08	14.22	92.7	7.3	5	30
150 µm	28.72	5.74	98.44	1.56	0	10
75 µm	7.03	1.41	99.85	0.15	0	0
Pan	0.13	0.03	99.88	0.12		
Total						

Fineness Modulus of fine aggregate = 3.81

⇨ Alawuha River samples affected by water flow of the river 3 (ALW_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.84	0.17	0.17	99.83	100	100
4.75 mm	51.24	10.25	10.42	89.58	95	100
2.36 mm	72.19	14.44	24.86	75.14	80	100
1.18 mm	106.94	21.39	46.25	53.75	50	85
600 µm	105.45	21.09	67.34	32.66	25	60
300 µm	84.29	16.86	84.2	15.8	5	30
150 µm	52.15	10.43	94.63	5.37	0	10
75 µm	24.92	4.98	99.61	0.39	0	0
Pan	1.01	0.2	99.81	0.19		
Total						

Fineness Modulus of fine aggregate = 3.28

1.5.Experimental Result of samples affected by leaves and flora (ALL)

Part 1.

River quarry: AL Supply point (code): ALL points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALL_1	Silt content	%	9.5	Jar test
		Bulking of sand	%	16	Jar test
		Unit weight	Kg/m^3	1328.65	Loose method
		Percentage void	%	15.35	Effect of compaction
		Specific gravity	-	2.43	ACI
		Absorption	%	4.8	ACI
		Organic impurity	Number	1	Color chart
2	ALL_2	Silt content	%	10.45	Jar test
		Bulking of sand	%	19	Jar test
		Unit weight	Kg/m^3	1433.25	Loose method
		Percentage void	%	19.54	Effect of compaction
		Specific gravity	-	2.5	ACI
		Absorption	%	5.15	ACI
		Organic impurity	Number	2	Color chart
3	ALL_3	Silt content	%	8	Jar test
		Bulking of sand	%	17.5	Jar test
		Unit weight	Kg/m^3	1524.86	Loose method
		Percentage void	%	15.25	Effect of compaction
		Specific gravity	-	2.65	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Alawuha River samples affected by leaves and flora (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	14.7	ACI mix design method for C-25
14^{th}	23	ACI mix design method for C-25
28^{th}	27	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Alawuha River samples affected by leaves and flora 1 (ALL_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.94	0.19	0.19	99.81	100	100
4.75 mm	44.24	8.85	9.04	90.96	95	100
2.36 mm	74.84	14.97	24.01	75.99	80	100
1.18 mm	87.71	17.54	41.55	58.45	50	85
600 µm	84.94	16.99	58.54	41.46	25	60
300 µm	114.94	22.99	81.53	18.47	5	30
150 µm	65.74	13.15	94.68	5.32	0	10
75 µm	22.76	4.55	99.23	0.77	0	0
Pan	3.37	0.67	99.9	0.1		
Total						

Fineness Modulus of fine aggregate = 3.1

⇨ Alawuha River samples affected by leaves and flora 2 (ALL_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.65	0.33	0.33	99.67	100	100
4.75 mm	64.24	12.85	13.18	86.82	95	100
2.36 mm	78.34	15.67	28.85	71.15	80	100
1.18 mm	92.17	18.43	47.28	52.72	50	85
600 µm	66.94	13.39	60.67	39.33	25	60
300 µm	137.49	27.5	88.17	11.83	5	30
150 µm	46.15	9.23	97.4	2.6	0	10
75 µm	11.36	2.27	99.67	0.33	0	0
Pan	0.83	0.17	99.84	0.16		
Total						

Fineness Modulus of fine aggregate = 3.36

⇨ Alawuha River samples affected by leaves and flora 3 (ALL_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.24	0.08	0.08	99.92	100	100
4.75 mm	56.21	11.24	11.32	88.68	95	100
2.36 mm	84.95	16.99	28.31	71.69	80	100
1.18 mm	110.45	22.09	50.4	49.6	50	85
600 µm	82.81	16.56	66.96	33.04	25	60
300 µm	99.94	19.99	86.95	13.05	5	30
150 µm	54.34	10.87	97.82	2.18	0	10
75 µm	9.69	1.94	99.76	0.24	0	0
Pan	0.83	0.17	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 3.42

1.6.Experimental Result of samples affected by production treatment and storage (ALP)
Part 1.
River quarry: AL Supply point (code): ALP points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	ALP_1	Silt content	%	0.25	Jar test
		Bulking of sand	%	10.5	Jar test
		Unit weight	Kg/m^3	1705.83	Loose method
		Percentage void	%	14.55	Effect of compaction
		Specific gravity	-	2.85	ACI
		Absorption	%	2.05	ACI
		Organic impurity	Number	1	Color chart
2	ALP_2	Silt content	%	0	Jar test
		Bulking of sand	%	8.5	Jar test
		Unit weight	Kg/m^3	1698.45	Loose method
		Percentage void	%	15.65	Effect of compaction
		Specific gravity	-	2.88	ACI
		Absorption	%	2.0	ACI
		Organic impurity	Number	1	Color chart
3	ALP_3	Silt content	%	0.25	Jar test
		Bulking of sand	%	11.85	Jar test
		Unit weight	Kg/m^3	1687.78	Loose method
		Percentage void	%	16.85	Effect of compaction
		Specific gravity	-	2.83	ACI
		Absorption	%	2.25	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

- ⇨ Alawuha River samples affected by production treatment and storage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	20.8	ACI mix design method for C-25
14^{th}	30.8	ACI mix design method for C-25
28^{th}	37.2	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Alawuha River samples affected by production treatment and storage; ALP (similar grading was used in all points)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	12.5	2.5	2.5	97.5	95	100
2.36 mm	37.5	7.5	10	90	80	100
1.18 mm	112.5	22.5	32.5	67.5	50	85
600 µm	125	25	57.5	42.5	25	60
300 µm	125	25	82.5	17.5	5	30
150 µm	62.5	12.5	95	5	0	10
75 µm	25	5	100	0	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 2.8

Appendix 3: Laboratory test results of Golina River Sand

3.1.Experimental Result of Golina controlled samples (GLC)

Part 1.

River quarry: GL Supply point (code): GLC points

No.	Supply points (by code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLC_1	Silt content	%	3.25	Jar test
		Bulking of sand	%	19.8	Jar test
		Unit weight	Kg/m^3	1578.9	Loose method
		Percentage void	%	17.02	Effect of compaction
		Specific gravity	-	2.81	ACI
		Absorption	%	3.1	ACI
		Organic impurity	Number	1	Color chart
2	GLC_2	Silt content	%	3.26	Jar test
		Bulking of sand	%	19.0	Jar test
		Unit weight	Kg/m^3	1610.92	Loose method
		Percentage void	%	18.25	Effect of compaction
		Specific gravity	-	2.79	ACI
		Absorption	%	3.71	ACI
		Organic impurity	Number	1	Color chart
3	GLC_3	Silt content	%	3.125	Jar test
		Bulking of sand	%	18.11	Jar test
		Unit weight	Kg/m^3	1706.83	Loose method
		Percentage void	%	14.98	Loose method
		Specific gravity	-	2.79	ACI
		Absorption	%	3.01	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Golina River Controlled sample (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13.6	ACI mix design method for C-25
14^{th}	21.1	ACI mix design method for C-25
28^{th}	26.8	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River Controlled sample 1 (GLC_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.12	0.42	0.42	99.58	100	100
4.75 mm	22.54	4.51	4.93	95.07	95	100
2.36 mm	51.85	10.37	15.3	84.7	80	100
1.18 mm	72.13	14.43	29.73	70.27	50	85
600 µm	182.6	36.52	66.25	33.75	25	60
300 µm	118.93	23.79	90.04	9.96	5	30
150 µm	29.8	5.96	96	4	0	10
75 µm	17.76	3.55	99.55	0.45	0	0
Pan	1.85	0.37	99.92	0.08		
Total						

Fineness Modulus of fine aggregate = 3.03

⇨ Golina River Controlled sample 2 (GLC_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	10.7	2.14	2.14	97.86	100	100
4.75 mm	19.7	3.94	6.08	93.92	95	100
2.36 mm	48.45	9.69	15.77	84.23	80	100
1.18 mm	83.95	16.79	32.56	67.44	50	85
600 µm	179	35.8	68.36	31.64	25	60
300 µm	128.9	25.78	94.14	5.86	5	30
150 µm	23.5	4.7	98.84	1.16	0	10
75 µm	3.9	0.78	99.62	0.38	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 3.18

⇨ Golina River Controlled sample 3 (GLC_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.5	0.5	0.5	99.5	100	100
4.75 mm	1.85	0.37	0.87	99.13	95	100
2.36 mm	39.85	7.97	8.84	91.16	80	100
1.18 mm	105.7	21.19	30.03	69.97	50	85
600 µm	210.2	42.04	72.07	27.93	25	60
300 µm	95.1	19.02	91.09	8.91	5	30
150 µm	29.63	5.93	97.02	2.98	0	10
75 µm	6.17	1.23	98.25	1.75	0	0
Pan	8.11	1.62	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 3.0

3.2.Experimental Result of samples affected by human and animal (GLH)
Part 1.
River quarry: GL Supply point (code) GLH points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLH_1	Silt content	%	7.5	Jar test
		Bulking of sand	%	21.3	Jar test
		Unit weight	Kg/m^3	1481.45	Loose method
		Percentage void	%	12.71	Effect of compaction
		Specific gravity	-	2.65	ACI
		Absorption	%	4.35	ACI
		Organic impurity	Number	1	Color chart
2	GLH_2	Silt content	%	8.5	Jar test
		Bulking of sand	%	19.85	Jar test
		Unit weight	Kg/m^3	1393.1	Loose method
		Percentage void	%	12.71	Effect of compaction
		Specific gravity	-	2.69	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	1	Color chart
3	GLH_3	Silt content	%	6.75	Jar test
		Bulking of sand	%	21.25	Jar test
		Unit weight	Kg/m^3	1293.1	Loose method
		Percentage void	%	12.71	Effect of compaction
		Specific gravity	-	2.72	ACI
		Absorption	%	7.15	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Golina River samples affected by human and animal (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	11.767	ACI mix design method for C-25
14^{th}	18.467	ACI mix design method for C-25
28^{th}	24.333	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River samples affected by human and animal 1 (GLH_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	12.46	2.49	2.49	97.51	80	100
1.18 mm	95.46	19.09	21.58	78.42	50	85
600 µm	54.87	10.97	32.55	67.45	25	60
300 µm	214.97	42.99	75.54	24.46	5	30
150 µm	85.84	17.17	92.71	7.29	0	10
75 µm	35.16	7.03	99.74	0.26	0	0
Pan	0.7	0.14	99.88	0.12		
Total						

Fineness Modulus of fine aggregate = 2.25

⇨ Golina River samples affected by human and animal 2 (GLH_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	12.46	2.49	2.49	97.51	80	100
1.18 mm	95.46	19.19	21.68	78.31	50	85
600 µm	54.87	10.97	32.65	67.35	25	60
300 µm	214.97	42.99	75.64	24.36	5	30
150 µm	85.84	17.17	92.81	7.19	0	10
75 µm	35.16	7.03	99.84	0.16	0	0
Pan	0.7	0.14	99.98	0.02		
Total						

Fineness Modulus of fine aggregate = 2.25

⇨ Golina River samples affected by human and animal 3 (GLH_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	5.35	1.07	1.07	98.93	95	100
2.36 mm	8.42	1.68	2.75	97.25	80	100
1.18 mm	110.74	22.15	24.9	75.1	50	85
600 µm	9.24	1.85	26.75	73.25	25	60
300 µm	239.18	47.84	74.59	25.41	5	30
150 µm	80.18	16.04	90.63	9.37	0	10
75 µm	45.62	9.12	99.75	0.25	0	0
Pan	0.41	0.08	99.83	0.17		
Total						

Fineness Modulus of fine aggregate = 2.21

3.3.Experimental Result samples affected by detergent and sewage (GLD)
Part 1.
River quarry: GL Supply point (code): GLD

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLD_1	Silt content	%	6.5	Jar test
		Bulking of sand	%	22.55	Jar test
		Unit weight	Kg/m^3	1599.7	Loose method
		Percentage void	%	13.17	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	5.25	ACI
		Organic impurity	Number	2	Color chart
2	GLD_2	Silt content	%	5.55	Jar test
		Bulking of sand	%	19.5	Jar test
		Unit weight	Kg/m^3	1578.76	Loose method
		Percentage void	%	14.87	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	4.75	ACI
		Organic impurity	Number	3	Color chart
3	GLD_3	Silt content	%	7.25	Jar test
		Bulking of sand	%	25.85	Jar test
		Unit weight	Kg/m^3	1658.98	Loose method
		Percentage void	%	13.71	Effect of compaction
		Specific gravity	-	2.58	ACI
		Absorption	%	6.75	ACI
		Organic impurity	Number	3	Color chart

Part 2. Concrete compressive strength

⇨ Golina River samples affected by detergent and sewage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13.7	ACI mix design method for C-25
14^{th}	17.97	ACI mix design method for C-25
28^{th}	22.03	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River samples affected by detergent and sewage 1 (GLD_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.83	0.36	0.36	99.64	100	100
4.75 mm	2.94	0.59	0.95	99.05	95	100
2.36 mm	81.2	16.24	17.19	82.81	80	100
1.18 mm	83.91	16.78	33.97	66.03	50	85
600 µm	115.29	23.06	57.03	42.97	25	60
300 µm	135.27	27.05	84.08	15.92	5	30
150 µm	43.61	8.72	92.8	7.2	0	10
75 µm	32.68	6.54	99.34	0.66	0	0
Pan	2.64	0.53	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 2.87

⇨ Golina River samples affected by detergent and sewage 2 (GLD_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.74	0.15	0.15	99.85	100	100
4.75 mm	1.06	0.21	0.36	99.64	95	100
2.36 mm	51.64	10.33	10.69	89.31	80	100
1.18 mm	90.17	18.03	28.72	71.28	50	85
600 µm	184.23	36.85	65.57	34.43	25	60
300 µm	111.46	22.29	87.86	12.14	5	30
150 µm	39.16	7.83	95.69	4.31	0	10
75 µm	13.29	2.66	98.35	1.65	0	0
Pan	8.04	1.61	99.96	0.04		
Total						

Fineness Modulus of fine aggregate = 2.89

⇨ Golina River samples affected by detergent and sewage 3 (GLD_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.10	0.22	0.22	99.78	100	100
4.75 mm	8.91	1.78	2	98	95	100
2.36 mm	42.24	8.45	10.45	89.55	80	100
1.18 mm	104.02	20.8	31.25	68.75	50	85
600 µm	145.56	29.11	60.36	39.64	25	60
300 µm	94.47	18.89	79.25	20.75	5	30
150 µm	74.12	14.82	94.07	5.93	0	10
75 µm	29.24	5.85	99.92	0.08	0	0
Pan	0.2	0.04	99.96	0.04		
Total						

Fineness Modulus of fine aggregate = 2.78

3.4.Experimental Result of samples affected by water flow of the river (GLW)

Part 1.

River quarry: GL Supply point (code): GLW points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLW_1	Silt content	%	8.95	Jar test
		Bulking of sand	%	22.55	Jar test
		Unit weight	Kg/m^3	1387.45	Loose method
		Percentage void	%	28.51	Effect of compaction
		Specific gravity	-	2.67	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	2	Color chart
2	GLW_2	Silt content	%	7.95	Jar test
		Bulking of sand	%	20.85	Jar test
		Unit weight	Kg/m^3	1471.68	Loose method
		Percentage void	%	19.52	Effect of compaction
		Specific gravity	-	2.58	ACI
		Absorption	%	3.99	ACI
		Organic impurity	Number	2	Color chart
3	GLW_3	Silt content	%	6.35	Jar test
		Bulking of sand	%	20.95	Jar test
		Unit weight	Kg/m^3	1648.95	Loose method
		Percentage void	%	14.12	Effect of compaction
		Specific gravity	-	2.75	ACI
		Absorption	%	4.55	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength

⇨ Golina River samples affected by water flow of the river (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	14.7	ACI mix design method for C-25
14^{th}	20.567	ACI mix design method for C-25
28^{th}	24.9	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River samples affected by water flow of the river 1 (GLW_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	21.21	4.24	4.24	95.76	100	100
4.75 mm	118.14	23.63	27.87	72.13	95	100
2.36 mm	134.27	26.85	54.72	45.28	80	100
1.18 mm	92.54	18.51	73.23	26.77	50	85
600 µm	94.26	18.85	92.08	7.92	25	60
300 µm	23.12	4.62	96.7	3.3	5	30
150 µm	15.26	3.05	99.75	0.25	0	10
75 µm	0.85	0.17	99.92	0.08	0	0
Pan	0.3	0.06	99.98	0.02		
Total						

Fineness Modulus of fine aggregate = 4.49

⇨ Golina River samples affected by water flow of the river 2 (GLW_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	9.26	1.86	0.86	99.14	100	100
4.75 mm	86.16	17.23	19.09	80.91	95	100
2.36 mm	167.61	33.52	52.61	47.39	80	100
1.18 mm	100.94	20.19	72.8	27.2	50	85
600 µm	94.15	18.83	91.63	8.37	25	60
300 µm	19.56	3.91	95.54	4.46	5	30
150 µm	22.1	4.42	99.96	0.04	0	10
75 µm	0.05	0.01	99.97	0.03	0	0
Pan	0.09	0.02	99.99	0.01		
Total						

Fineness Modulus of fine aggregate = 4.33

⇨ Golina River samples affected by water flow of the river 3 (GLW_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.26	0.25	0.25	99.75	100	100
4.75 mm	166.85	33.37	33.62	66.38	95	100
2.36 mm	169.32	33.86	67.48	32.52	80	100
1.18 mm	55.15	11.03	78.51	21.49	50	85
600 µm	45.76	9.15	87.66	12.34	25	60
300 µm	49.21	9.84	97.5	2.7	5	30
150 µm	10.94	2.19	99.69	0.31	0	10
75 µm	0.55	0.11	99.8	0.2	0	0
Pan	0.78	0.16	99.96	0.04		
Total						

Fineness Modulus of fine aggregate = 4.65

3.5.Experimental Result of samples affected by leaves and flora (GLL)

Part 1.

River quarry: GL Supply point (code): GLL points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLL_1	Silt content	%	11.15	Jar test
		Bulking of sand	%	19.95	Jar test
		Unit weight	Kg/m^3	1387.85	Loose method
		Percentage void	%	15.31	Effect of compaction
		Specific gravity	-	2.54	ACI
		Absorption	%	3.99	ACI
		Organic impurity	Number	2	Color chart
2	GLL_2	Silt content	%	9.18	Jar test
		Bulking of sand	%	20.21	Jar test
		Unit weight	Kg/m^3	1297.14	Loose method
		Percentage void	%	17.36	Effect of compaction
		Specific gravity	-	2.65	ACI
		Absorption	%	4.15	ACI
		Organic impurity	Number	2	Color chart
3	GLL_3	Silt content	%	8.22	Jar test
		Bulking of sand	%	19.16	Jar test
		Unit weight	Kg/m^3	1454.98	Loose method
		Percentage void	%	14.61	Effect of compaction
		Specific gravity	-	2.66	ACI
		Absorption	%	4.44	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Golina River samples affected by leaves and flora (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	12.7	ACI mix design method for C-25
14^{th}	20.1	ACI mix design method for C-25
28^{th}	23.8	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River samples affected by leaves and flora 1 (GLL_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	13.62	2.72	2.72	97.28	95	100
2.36 mm	65.52	13.1	15.82	84.18	80	100
1.18 mm	127.21	25.44	41.26	58.74	50	85
600 µm	99.25	19.85	61.11	38.89	25	60
300 µm	101.34	20.27	81.38	18.62	5	30
150 µm	66.14	13.23	94.61	5.39	0	10
75 µm	24.15	4.83	99.44	0.56	0	0
Pan	2.74	0.55	99.99	0.01		
Total						

Fineness Modulus of fine aggregate = 2.97

⇨ Golina River samples affected by leaves and flora 2 (GLL_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.56	0.31	0.31	99.69	100	100
4.75 mm	33.81	6.76	7.07	92.97	95	100
2.36 mm	34.12	6.8	13.87	86.13	80	100
1.18 mm	115.29	23.06	36.93	63.07	50	85
600 µm	97.31	19.46	56.39	43.61	25	60
300 µm	110.64	22.13	78.52	21.48	5	30
150 µm	53.64	10.73	89.25	10.75	0	10
75 µm	41.85	8.37	97.62	2.38	0	0
Pan	11.31	2.26	99.88	0.12		
Total						

Fineness Modulus of fine aggregate = 2.82

⇨ Golina River samples affected by leaves and flora 3 (GLL_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.78	0.16	0.16	99.84	100	100
4.75 mm	11.23	2.25	2.41	97.59	95	100
2.36 mm	50.21	10.04	12.45	87.55	80	100
1.18 mm	98.32	19.66	32.11	67.89	50	85
600 µm	85.62	17.12	49.23	50.77	25	60
300 µm	133.1	26.62	75.85	24.15	5	30
150 µm	65.64	13.13	88.98	11.02	0	10
75 µm	52.31	10.46	99.44	0.56	0	0
Pan	2.67	0.53	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 2.61

3.6.Experimental Result of samples affected by production treatment and storage (GLP)

Part 1.

River quarry: GL Supply point (code): GLP points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	GLP_1	Silt content	%	0.23	Jar test
		Bulking of sand	%	11.5	Jar test
		Unit weight	Kg/m^3	1692.14	Loose method
		Percentage void	%	9.17	Effect of compaction
		Specific gravity	-	2.80	ACI
		Absorption	%	2.33	ACI
		Organic impurity	Number	1	Color chart
2	GLP_2	Silt content	%	0.0	Jar test
		Bulking of sand	%	8.5	Jar test
		Unit weight	Kg/m^3	1712.16	Loose method
		Percentage void	%	16.49	Effect of compaction
		Specific gravity	-	2.83	ACI
		Absorption	%	2.55	ACI
		Organic impurity	Number	1	Color chart
3	GLP_3	Silt content	%	0.75	Jar test
		Bulking of sand	%	15.85	Jar test
		Unit weight	Kg/m^3	1807.94	Loose method
		Percentage void	%	11.94	Effect of compaction
		Specific gravity	-	2.79	ACI
		Absorption	%	2.15	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Golina River samples affected by production treatment and storage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	20.2	ACI mix design method for C-25
14^{th}	26.8	ACI mix design method for C-25
28^{th}	31.9	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Golina River samples affected by production treatment and storage; GLP (similar grading was used in all points)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	12.5	2.5	2.5	97.5	95	100
2.36 mm	37.5	7.5	10	90	80	100
1.18 mm	112.5	22.5	32.5	67.5	50	85
600 µm	125	25	57.5	42.5	25	60
300 µm	125	25	82.5	17.5	5	30
150 µm	62.5	12.5	95	5	0	10
75 µm	25	5	100	0	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 2.8

Appendix 4: Laboratory test results of Hormat River Sand

4.1.Experimental Result of Hormat controlled samples (HRC)

Part 1.

River quarry: HR Supply point (code): HRC points

No.	Supply points (by code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRC_1	Silt content	%	4.5	Jar test
		Bulking of sand	%	17	Jar test
		Unit weight	Kg/m^3	1692.1	Loose method
		Percentage void	%	16.57	Effect of compaction
		Specific gravity	-	2.9	ACI
		Absorption	%	2.7	ACI
		Organic impurity	Number	1	Color chart
2	HRC_2	Silt content	%	4.64	Jar test
		Bulking of sand	%	20	Jar test
		Unit weight	Kg/m^3	1683.13	Loose method
		Percentage void	%	17	Loose method
		Specific gravity	-	2.68	ACI
		Absorption	%	2.73	ACI
		Organic impurity	Number	1	Color chart
3	HRC_3	Silt content	%	3.0	Jar test
		Bulking of sand	%	12.04	Jar test
		Unit weight	Kg/m^3	1665.99	Loose method
		Percentage void	%	10.07	Loose method
		Specific gravity	-	2.81	ACI
		Absorption	%	2.66	ACI
		Organic impurity	Number	1	Color chart

Part 3. Concrete compressive strength

⇨ Hormat River Controlled sample (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	18.6	ACI mix design method for C-25
14^{th}	24	ACI mix design method for C-25
28^{th}	26.5	ACI mix design method for C-25

Part 2. Sieve Analysis

⇨ Hormat River Controlled sample 1 (HRC_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.15	0.03	0.03	99.97	100	100
4.75 mm	12.81	2.56	2.59	97.41	95	100
2.36 mm	45.23	9.05	11.64	88.36	80	100
1.18 mm	142.92	28.44	40.08	59.92	50	85
600 µm	121.36	24.27	64.35	35.65	25	60
300 µm	78.4	15.68	80.03	19.97	5	30
150 µm	67.12	13.42	93.45	6.55	0	10
75 µm	28.29	5.66	99.11	0.89	0	0
Pan	3.24	0.65	99.76	0.24		
Total						

Fineness Modulus of fine aggregate = 2.92

⇨ Hormat River Controlled sample 2 (HRC_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.4	0.48	0.48	99.52	100	100
4.75 mm	6.66	1.33	1.81	98.19	95	100
2.36 mm	43.8	8.76	10.57	89.43	80	100
1.18 mm	122.31	24.46	35.03	64.97	50	85
600 µm	172.65	34.53	69.56	30.44	25	60
300 µm	121.5	24.3	93.86	6.14	5	30
150 µm	24.19	4.84	98.7	1.3	0	10
75 µm	5.62	1.12	99.82	0.18	0	0
Pan	0.25	0.05	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 3.10

⇨ Hormat River Controlled sample 3 (HRC_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	6.95	1.39	1.39	98.61	100	100
4.75 mm	18.57	3.72	5.11	94.89	95	100
2.36 mm	34.21	6.84	11.95	88.05	80	100
1.18 mm	60.21	12.04	23.99	76.01	50	85
600 µm	121.25	24.25	48.24	51.76	25	60
300 µm	142.83	28.57	76.81	23.19	5	30
150 µm	93.78	18.76	95.57	4.43	0	10
75 µm	18.24	3.65	99.22	0.78	0	0
Pan	3.24	0.65	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 2.63

4.2.Experimental Result of samples affected by human and animal (HRH)
Part 1.
River quarry: HR Supply point (code) HRH points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRH_1	Silt content	%	6.5	Jar test
		Bulking of sand	%	22.3	Jar test
		Unit weight	Kg/m^3	1626.5	Loose method
		Percentage void	%	9.03	Effect of compaction
		Specific gravity	-	2.7	ACI
		Absorption	%	3.23	ACI
		Organic impurity	Number	1	Color chart
2	HRH_2	Silt content	%	9.98	Jar test
		Bulking of sand	%	20.21	Jar test
		Unit weight	Kg/m^3	1393.74	Loose method
		Percentage void	%	20.21	Effect of compaction
		Specific gravity	-	2.67	ACI
		Absorption	%	3.74	ACI
		Organic impurity	Number	1	Color chart
3	HRH_3	Silt content	%	6.5	Jar test
		Bulking of sand	%	22.3	Jar test
		Unit weight	Kg/m^3	1261.66	Loose method
		Percentage void	%	23.17	Effect of compaction
		Specific gravity	-	2.66	ACI
		Absorption	%	3.15	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Hormat River samples affected by human and animal (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13	ACI mix design method for C-25
14^{th}	18.0667	ACI mix design method for C-25
28^{th}	22.6	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Hormat River samples affected by human and animal 1 (HRH_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	6.19	1.24	1.24	98.76	80	100
1.18 mm	98.23	19.65	20.89	79.11	50	85
600 µm	105.63	21.13	42.02	57.98	25	60
300 µm	130.8	26.16	68.18	31.82	5	30
150 µm	89.37	17.87	86.05	13.95	0	10
75 µm	46.23	9.25	95.3	4.7	0	0
Pan	22.73	4.55	99.85	0.15		
Total						

Fineness Modulus of fine aggregate = 2.18

⇨ Hormat River samples affected by human and animal 2 (HRH_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	1.2	0.24	0.24	99.76	95	100
2.36 mm	5.32	1.06	1.3	98.7	80	100
1.18 mm	96.35	19.27	20.57	79.43	50	85
600 µm	115.49	23.1	43.67	56.33	25	60
300 µm	124.26	24.85	68.52	31.48	5	30
150 µm	105.24	21.05	89.57	10.43	0	10
75 µm	50.3	10.06	99.63	0.37	0	0
Pan	1.28	0.26	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 2.24

⇨ Hormat River samples affected by human and animal 3 (HRH_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	3.84	0.77	0.77	99.23	95	100
2.36 mm	32.64	6.53	7.3	92.7	80	100
1.18 mm	84.26	16.85	24.15	75.85	50	85
600 µm	101.21	20.24	44.39	55.61	25	60
300 µm	110.55	22.11	66.5	33.5	5	30
150 µm	110.46	22.09	88.59	11.41	0	10
75 µm	49.54	9.91	98.5	1.5	0	0
Pan	7.18	1.44	99.94	0.06		
Total						

Fineness Modulus of fine aggregate = 2.32

4.3.Experimental Result samples affected by detergent and sewage (HRD)
Part 1.
River quarry: HR   Supply point (code): HRD

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRD_1	Silt content	%	9.15	Jar test
		Bulking of sand	%	21.15	Jar test
		Unit weight	Kg/m^3	1654.84	Loose method
		Percentage void	%	15.54	Effect of compaction
		Specific gravity	-	2.71	ACI
		Absorption	%	3.99	ACI
		Organic impurity	Number	3	Color chart
2	HRD_2	Silt content	%	11.35	Jar test
		Bulking of sand	%	20.13	Jar test
		Unit weight	Kg/m^3	1782.34	Loose method
		Percentage void	%	16.84	Effect of compaction
		Specific gravity	-	2.63	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	3	Color chart
3	HRD_3	Silt content	%	10.12	Jar test
		Bulking of sand	%	19.95	Jar test
		Unit weight	Kg/m^3	1768.24	Loose method
		Percentage void	%	16.14	Effect of compaction
		Specific gravity	-	2.63	ACI
		Absorption	%	3.13	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength

⇨ Hormat River samples affected by detergent and sewage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7th	14.3	ACI mix design method for C-25
14th	18.7	ACI mix design method for C-25
28th	20.77	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Hormat River samples affected by detergent and sewage 1 (HRD_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	3.11	0.63	0.63	99.37	100	100
4.75 mm	21.32	4.26	4.89	95.1	95	100
2.36 mm	48.77	9.75	14.64	85.36	80	100
1.18 mm	99.78	19.96	34.6	65.4	50	85
600 µm	123.38	24.68	59.28	40.72	25	60
300 µm	125.39	25.08	84.36	15.64	5	30
150 µm	56.3	11.26	95.62	4.38	0	10
75 µm	17.26	3.45	99.07	0.93	0	0
Pan	3.73	0.75	99.82	0.18		
Total						

Fineness Modulus of fine aggregate = 2.94

⇨ Hormat River samples affected by detergent and sewage 2 (HRD_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	4.26	0.85	0.85	99.15	100	100
4.75 mm	15.29	3.06	3.91	96.09	95	100
2.36 mm	36.21	7.24	11.15	88.85	80	100
1.18 mm	110.58	22.12	33.27	66.73	50	85
600 µm	167.26	33.45	66.72	33.28	25	60
300 µm	116.37	23.27	89.99	10.01	5	30
150 µm	44.94	8.99	98.98	1.02	0	10
75 µm	3.12	0.62	99.6	0.4	0	0
Pan	1.64	0.33	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 3.05

⇨ Hormat River samples affected by detergent and sewage 3 (HRD_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.24	0.25	0.25	99.75	100	100
4.75 mm	35.94	7.19	7.44	92.56	95	100
2.36 mm	51.94	10.39	17.83	82.17	80	100
1.18 mm	99.81	19.96	37.79	62.21	50	85
600 µm	116.45	23.29	61.08	38.92	25	60
300 µm	112.87	22.57	83.65	16.35	5	30
150 µm	55.85	11.17	94.82	5.18	0	10
75 µm	22.14	4.43	99.25	0.75	0	0
Pan	2.89	0.58	99.83	0.17		
Total						

Fineness Modulus of fine aggregate = 3.03

4.4.Experimental Result of samples affected by water flow of the river (HRW)

Part 1.

River quarry: HR Supply point (code): HRW points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRW_1	Silt content	%	8.85	Jar test
		Bulking of sand	%	27.95	Jar test
		Unit weight	Kg/m^3	1431.86	Loose method
		Percentage void	%	26.75	Effect of compaction
		Specific gravity	-	2.55	ACI
		Absorption	%	3.87	ACI
		Organic impurity	Number	2	Color chart
2	HRW_2	Silt content	%	7.82	Jar test
		Bulking of sand	%	24.95	Jar test
		Unit weight	Kg/m^3	1562.94	Loose method
		Percentage void	%	19.41	Effect of compaction
		Specific gravity	-	2.58	ACI
		Absorption	%	2.95	ACI
		Organic impurity	Number	1	Color chart
3	HRW_3	Silt content	%	9.98	Jar test
		Bulking of sand	%	23.95	Jar test
		Unit weight	Kg/m^3	1709.64	Loose method
		Percentage void	%	10.94	Loose method
		Specific gravity	-	2.60	ACI
		Absorption	%	3.35	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength

⇨ Hormat River samples affected by water flow of the river (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	15.8	ACI mix design method for C-25
14^{th}	19.8	ACI mix design method for C-25
28^{th}	23.97	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Hormat River samples affected by water flow of the river 1 (HRW_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	5.15	1.03	1.03	98.97	100	100
4.75 mm	79.32	15.86	16.89	83.11	95	100
2.36 mm	95.25	19.05	35.94	64.06	80	100
1.18 mm	121.08	24.22	60.16	39.84	50	85
600 µm	124.25	24.85	85.01	14.99	25	60
300 µm	42.26	8.45	93.46	6.54	5	30
150 µm	30.93	6.19	99.65	0.35	0	10
75 µm	1.22	0.24	99.89	0.11	0	0
Pan	0.2	0.04	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 3.92

⇨ Hormat River samples affected by water flow of the river 2 (HRW_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.34	0.27	0.27	99.73	100	100
4.75 mm	96.47	19.29	19.56	80.44	95	100
2.36 mm	112.95	22.59	42.15	57.85	80	100
1.18 mm	139.53	27.97	70.12	29.88	50	85
600 µm	66.21	13.24	83.36	16.64	25	60
300 µm	33.53	6.71	90.07	9.93	5	30
150 µm	42.51	8.5	98.57	1.43	0	10
75 µm	5.36	1.07	99.64	0.36	0	0
Pan	1.75	0.35	99.99	0.01		
Total						

Fineness Modulus of fine aggregate = 4.04

⇨ Hormat River samples affected by water flow of the river 3 (HRW_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	3.12	0.62	0.62	99.38	100	100
4.75 mm	65.24	13.05	13.67	86.33	95	100
2.36 mm	164.79	32.96	46.63	53.37	80	100
1.18 mm	105.26	21.05	67.68	32.32	50	85
600 µm	72.84	14.57	82.25	17.75	25	60
300 µm	55.21	11.04	93.29	6.71	5	30
150 µm	22.01	4.4	97.69	2.31	0	10
75 µm	7.89	1.58	99.27	0.73	0	0
Pan	2.87	0.57	99.84	0.12		
Total						

Fineness Modulus of fine aggregate = 4.02

4.5.Experimental Result of samples affected by leaves and flora (HRL)

Part 1.

River quarry: HR Supply point (code): HRL points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRL_1	Silt content	%	12.12	Jar test
		Bulking of sand	%	22.5	Jar test
		Unit weight	Kg/m^3	1422.81	Loose method
		Percentage void	%	14.97	Effect of compaction
		Specific gravity	-	2.63	ACI
		Absorption	%	3.01	ACI
		Organic impurity	Number	2	Color chart
2	HRL_2	Silt content	%	9.89	Jar test
		Bulking of sand	%	21.73	Jar test
		Unit weight	Kg/m^3	1358.76	Loose method
		Percentage void	%	15.27	Effect of compaction
		Specific gravity	-	2.67	ACI
		Absorption	%	3.54	ACI
		Organic impurity	Number	1	Color chart
3	HRL_3	Silt content	%	10.5	Jar test
		Bulking of sand	%	24.65	Jar test
		Unit weight	Kg/m^3	1504.62	Loose method
		Percentage void	%	12.93	Effect of compaction
		Specific gravity	-	2.59	ACI
		Absorption	%	3.33	ACI
		Organic impurity	Number	2	Color chart

Part 3. Concrete compressive strength

⇨ Hormat River samples affected by leaves and flora (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	15.1	ACI mix design method for C-25
14^{th}	19.9	ACI mix design method for C-25
28^{th}	23.5	ACI mix design method for C-25

Part 2. Sieve Analysis

⇨ Hormat River samples affected by leaves and flora 1 (HRL_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	5.8	1.16	1.16	98.84	95	100
2.36 mm	45.28	9.06	10.22	89.78	80	100
1.18 mm	74.21	14.84	25.06	74.94	50	85
600 µm	88.34	17.67	42.73	57.27	25	60
300 µm	119.54	23.91	66.64	33.36	5	30
150 µm	127.27	25.45	92.09	7.91	0	10
75 µm	32.45	6.49	98.58	1.42	0	0
Pan	6.24	1.25	99.83	0.17		
Total						

Fineness Modulus of fine aggregate = 2.38

⇨ Hormat River samples affected by leaves and flora 2 (HRL_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.11	0.22	0.22	99.78	100	100
4.75 mm	11.24	2.25	2.47	97.53	95	100
2.36 mm	22.64	4.53	7	93	80	100
1.18 mm	32.24	6.45	13.45	86.55	50	85
600 µm	56.32	11.26	24.71	75.29	25	60
300 µm	164.39	32.88	57.59	42.41	5	30
150 µm	156.64	31.33	88.92	11.08	0	10
75 µm	44.87	8.97	97.89	2.11	0	0
Pan	9.92	1.98	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 1.94

⇨ Hormat River samples affected by leaves and flora 3 (HRL_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.99	0.6	0.6	99.4	100	100
4.75 mm	5.27	1.05	1.65	98.35	95	100
2.36 mm	46.32	9.26	10.91	89.09	80	100
1.18 mm	84.96	16.99	27.9	72.1	50	85
600 µm	98.95	19.79	47.69	52.31	25	60
300 µm	128.9	25.78	73.47	26.53	5	30
150 µm	99.23	19.85	93.32	6.68	0	10
75 µm	28.97	5.79	99.11	0.89	0	0
Pan	3.92	0.78	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 2.55

4.6.Experimental Result of samples affected by production treatment and storage (HRP)
Part 1.
River quarry: HR Supply point (code): HRP points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	HRP_1	Silt content	%	0.5	Jar test
		Bulking of sand	%	12.35	Jar test
		Unit weight	Kg/m^3	1807.46	Loose method
		Percentage void	%	11.49	Effect of compaction
		Specific gravity	-	2.85	ACI
		Absorption	%	2.25	ACI
		Organic impurity	Number	1	Color chart
2	HRP_2	Silt content	%	0.0	Jar test
		Bulking of sand	%	10.89	Jar test
		Unit weight	Kg/m^3	1789.16	Loose method
		Percentage void	%	9.47	Effect of compaction
		Specific gravity	-	2.89	ACI
		Absorption	%	2.29	ACI
		Organic impurity	Number	1	Color chart
3	HRP_3	Silt content	%	0.35	Jar test
		Bulking of sand	%	10.25	Jar test
		Unit weight	Kg/m^3	1699.97	Loose method
		Percentage void	%	14.65	Effect of compaction
		Specific gravity	-	2.87	ACI
		Absorption	%	2.5	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

- ⇨ Hormat River samples affected by production treatment and storage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	23.97	ACI mix design method for C-25
14^{th}	33.1	ACI mix design method for C-25
28^{th}	39.1	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Hormat River samples affected by production treatment and storage; HRP (similar grading was used in all points)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	12.5	2.5	2.5	97.5	95	100
2.36 mm	37.5	7.5	10	90	80	100
1.18 mm	112.5	22.5	32.5	67.5	50	85
600 µm	125	25	57.5	42.5	25	60
300 µm	125	25	82.5	17.5	5	30
150 µm	62.5	12.5	95	5	0	10
75 µm	25	5	100	0	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 2.8

Appendix 5: Laboratory test results of Mersa River Sand

5.1.Experimental Result of Mersa controlled samples (MRC)

Part 1.

River quarry: MR   Supply point (code): MRC points

No.	Supply points (by code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRC_1	Silt content	%	3.55	Jar test
		Bulking of sand	%	14.5	Jar test
		Unit weight	Kg/m^3	1673.68	Loose method
		Percentage void	%	18.98	Effect of compaction
		Specific gravity	-	2.81	ACI
		Absorption	%	3.25	ACI
		Organic impurity	Number	1	Color chart
2	MRC_2	Silt content	%	2.5	Jar test
		Bulking of sand	%	12.5	Jar test
		Unit weight	Kg/m^3	1665.6	Loose method
		Percentage void	%	19	Effect of compaction
		Specific gravity	-	3.06	ACI
		Absorption	%	3.24	ACI
		Organic impurity	Number	1	Color chart
3	MRC_3	Silt content	%	5.56	Jar test
		Bulking of sand	%	21.21	Jar test
		Unit weight	Kg/m^3	1700.06	Loose method
		Percentage void	%	13.11	Effect of compaction
		Specific gravity	-	2.94	ACI
		Absorption	%	4.31	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Mersa River Controlled sample (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	18.1	ACI mix design method for C-25
14^{th}	23.2	ACI mix design method for C-25
28^{th}	27.5	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Mersa River Controlled sample 1 (MRC_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	3.31	0.66	0.66	99.34	100	100
4.75 mm	108.61	21.72	22.38	77.62	95	100
2.36 mm	102.37	20.47	42.85	57.15	80	100
1.18 mm	97.14	19.43	62.28	37.72	50	85
600 µm	92.31	18.46	80.74	19.26	25	60
300 µm	48.23	9.65	90.39	9.61	5	30
150 µm	28.39	5.68	96.07	3.93	0	10
75 µm	17.74	3.55	99.62	0.38	0	0
Pan	1.68	0.34	99.96	0.04		
Total						

Fineness Modulus of fine aggregate = 3.95

⇨ Mersa River Controlled sample 2 (MRC_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	9.32	1.86	1.86	98.14	100	100
4.75 mm	115.31	23.06	24.92	75.08	95	100
2.36 mm	119.7	23.94	48.86	51.14	80	100
1.18 mm	81.7	16.34	65.2	34.8	50	85
600 µm	91.8	18.36	83.56	16.44	25	60
300 µm	64.14	12.83	96.39	3.61	5	30
150 µm	15.3	3.06	99.45	0.55	0	10
75 µm	1.15	0.23	99.68	0.32	0	0
Pan	0.96	0.19	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 4.20

⇨ Mersa River Controlled sample 3 (MRC_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	8.7	1.74	1.74	98.26	100	100
4.75 mm	62.22	12.44	14.18	85.82	95	100
2.36 mm	152.3	30.46	44.64	55.36	80	100
1.18 mm	71.2	14.24	58.88	41.12	50	85
600 µm	98.24	19.65	78.53	21.47	25	60
300 µm	61.13	12.23	90.76	9.24	5	30
150 µm	34.25	6.85	97.61	2.39	0	10
75 µm	10.94	2.19	99.8	0.2	0	0
Pan	0.72	0.14	99.94	0.06		
Total						

Fineness Modulus of fine aggregate = 3.86

5.2.Experimental Result of samples affected by human and animal (MRH)
Part 1.
River quarry: MR Supply point (code) MRH points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRH_1	Silt content	%	6.98	Jar test
		Bulking of sand	%	22.35	Jar test
		Unit weight	Kg/m^3	1513.9	Loose method
		Percentage void	%	14.93	Effect of compaction
		Specific gravity	-	2.73	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	1	Color chart
2	MRH_2	Silt content	%	4.5	Jar test
		Bulking of sand	%	23.45	Jar test
		Unit weight	Kg/m^3	1529.73	Loose method
		Percentage void	%	16.21	Effect of compaction
		Specific gravity	-	2.79	ACI
		Absorption	%	4.54	ACI
		Organic impurity	Number	1	Color chart
3	MRH_3	Silt content	%	5.23	Jar test
		Bulking of sand	%	21.24	Jar test
		Unit weight	Kg/m^3	1365.78	Loose method
		Percentage void	%	21.94	Effect of compaction
		Specific gravity	-	2.72	ACI
		Absorption	%	4.22	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Mersa River samples affected by human and animal (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	10.8	ACI mix design method for C-25
14^{th}	19.9	ACI mix design method for C-25
28^{th}	23.1	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Mersa River samples affected by human and animal 1 (MRH_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	1.02	0.2	0.2	99.8	95	100
2.36 mm	30.24	6.05	6.25	93.75	80	100
1.18 mm	48.76	9.75	16	84	50	85
600 µm	82.37	16.47	32.47	67.53	25	60
300 µm	123.35	24.67	57.14	42.86	5	30
150 µm	132.98	26.6	83.74	16.26	0	10
75 µm	68.75	13.75	97.49	2.51	0	0
Pan	11.98	2.4	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 1.96

⇨ Mersa River samples affected by human and animal 2 (MRH_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	26.14	5.23	5.23	94.77	80	100
1.18 mm	58.31	11.66	16.89	83.11	50	85
600 µm	79.16	15.83	32.72	67.28	25	60
300 µm	162.34	32.47	65.19	34.81	5	30
150 µm	116.81	23.36	88.55	11.45	0	10
75 µm	52.61	10.52	99.07	0.93	0	0
Pan	3.64	0.73	99.8	0.2		
Total						

Fineness Modulus of fine aggregate = 2.09

⇨ Mersa River samples affected by human and animal 3 (MRH_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	2.14	0.43	0.43	99.57	95	100
2.36 mm	38.94	7.79	8.22	91.78	80	100
1.18 mm	48.26	9.65	17.87	82.13	50	85
600 µm	66.84	13.37	31.24	68.76	25	60
300 µm	150.93	30.19	61.43	38.57	5	30
150 µm	134.38	26.88	88.31	11.69	0	10
75 µm	51.28	10.26	98.57	1.43	0	0
Pan	6.25	1.25	99.82	0.18		
Total						

Fineness Modulus of fine aggregate = 2.08

5.3.Experimental Result samples affected by detergent and sewage (MRD)
Part 1.
River quarry: MR Supply point (code): MRD

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRD_1	Silt content	%	6.23	Jar test
		Bulking of sand	%	19.25	Jar test
		Unit weight	Kg/m^3	1621.6	Loose method
		Percentage void	%	17.22	Effect of compaction
		Specific gravity	-	2.67	ACI
		Absorption	%	3.12	ACI
		Organic impurity	Number	4	Color chart
2	MRD_2	Silt content	%	5.45	Jar test
		Bulking of sand	%	19.25	Jar test
		Unit weight	Kg/m^3	1694.14	Loose method
		Percentage void	%	17.19	Effect of compaction
		Specific gravity	-	2.63	ACI
		Absorption	%	3.85	ACI
		Organic impurity	Number	4	Color chart
3	MRD_3	Silt content	%	8.85	Jar test
		Bulking of sand	%	20.19	Jar test
		Unit weight	Kg/m^3	1721.94	Loose method
		Percentage void	%	19.95	Effect of compaction
		Specific gravity	-	2.63	ACI
		Absorption	%	3.58	ACI
		Organic impurity	Number	3	Color chart

Part 2. Concrete compressive strength
⇨ Mersa River samples affected by detergent and sewage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	11.9	ACI mix design method for C-25
14^{th}	20.8	ACI mix design method for C-25
28^{th}	22.9	ACI mix design method for C-25

Part 3. Sieve Analysis
⇨ Mersa River samples affected by detergent and sewage 1 (MRD_1)
Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	5.1	1.02	1.02	98.98	100	100
4.75 mm	35.63	7.13	8.15	91.85	95	100
2.36 mm	108.25	21.65	29.8	70.2	80	100
1.18 mm	111.79	22.36	52.16	47.84	50	85
600 µm	110.15	22.03	74.19	25.81	25	60
300 µm	54.28	10.86	85.05	14.95	5	30
150 µm	61.89	12.38	97.43	2.57	0	10
75 µm	9.87	1.97	99.4	0.6	0	0
Pan	2.08	0.42	99.82	0.18		
Total						

Fineness Modulus of fine aggregate = 3.48

⇨ Mersa River samples affected by detergent and sewage 2 (MRD_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	7.24	1.45	1.45	98.55	100	100
4.75 mm	99.81	19.96	21.41	78.59	95	100
2.36 mm	113.7	22.74	44.15	55.85	80	100
1.18 mm	82.61	16.52	60.67	39.33	50	85
600 µm	74.28	14.86	75.53	24.47	25	60
300 µm	72.61	14.52	90.05	9.95	5	30
150 µm	35.64	7.13	97.18	2.82	0	10
75 µm	12.97	2.59	99.77	0.23	0	0
Pan	1	0.2	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 3.90

⇨ Mersa River samples affected by detergent and sewage 3 (MRD_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.36	0.27	0.27	99.73	100	100
4.75 mm	86.29	17.26	17.57	82.43	95	100
2.36 mm	123.79	24.78	42.31	57.69	80	100
1.18 mm	85.24	17.05	59.36	40.64	50	85
600 µm	84.35	16.87	76.23	23.77	25	60
300 µm	63.71	12.74	88.97	11.03	5	30
150 µm	41.3	8.26	97.23	2.77	0	10
75 µm	11.91	2.38	99.61	0.39	0	0
Pan	1.27	0.25	99.86	0.14		
Total						

Fineness Modulus of fine aggregate = 3.82

5.4.Experimental Result of samples affected by water flow of the river (MRW)
Part 1.
River quarry: MR Supply point (code): MRW points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRW_1	Silt content	%	1.25	Jar test
		Bulking of sand	%	16.25	Jar test
		Unit weight	Kg/m^3	1324.27	Loose method
		Percentage void	%	31.27	Effect of compaction
		Specific gravity	-	2.75	ACI
		Absorption	%	2.99	ACI
		Organic impurity	Number	1	Color chart
2	MRW_2	Silt content	%	11.23	Jar test
		Bulking of sand	%	22.45	Jar test
		Unit weight	Kg/m^3	1610.04	Loose method
		Percentage void	%	23.97	Effect of compaction
		Specific gravity	-	2.61	ACI
		Absorption	%	3.59	ACI
		Organic impurity	Number	2	Color chart
3	ALW_3	Silt content	%	8.75	Jar test
		Bulking of sand	%	20.95	Jar test
		Unit weight	Kg/m^3	1494.38	Loose method
		Percentage void	%	20.93	Effect of compaction
		Specific gravity	-	2.66	ACI
		Absorption	%	4.15	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength
⇨ Mersa River samples affected by water flow of the river (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	14.5	ACI mix design method for C-25
14^{th}	21.5	ACI mix design method for C-25
28^{th}	25.6	ACI mix design method for C-25

Part 2. Sieve Analysis
⇨ Mersa River samples affected by water flow of the river 1 (MRW_1)
Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	23.86	4.77	4.77	95.23	100	100
4.75 mm	135.94	27.19	31.96	68.04	95	100
2.36 mm	136.79	27.36	59.32	40.68	80	100
1.18 mm	89.34	17.87	77.19	22.81	50	85
600 µm	62.31	12.46	89.65	10.35	25	60
300 µm	32.18	6.44	96.09	3.91	5	30
150 µm	15.58	3.12	99.21	0.79	0	10
75 µm	3.1	0.62	99.83	0.17	0	0
Pan	0.08	0.02	99.85	0.15		
Total						

Fineness Modulus of fine aggregate = 4.58

⇨ Mersa River samples affected by water flow of the river 2 (MRW_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	10.35	2.07	2.07	97.93	100	100
4.75 mm	141.37	28.27	30.34	69.66	95	100
2.36 mm	133.64	26.73	57.07	42.93	80	100
1.18 mm	109.46	21.89	78.96	21.04	50	85
600 µm	56.89	11.38	90.34	9.66	25	60
300 µm	30.38	6.08	96.42	3.58	5	30
150 µm	12.94	2.59	99.01	0.99	0	10
75 µm	2.81	0.56	99.57	0.43	0	0
Pan	1.94	0.39	99.96	0.04		
Total						

Fineness Modulus of fine aggregate = 4.54

⇨ Mersa River samples affected by water flow of the river 3 (MRW_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	4.28	0.86	0.86	99.14	100	100
4.75 mm	138.94	27.78	28.64	71.36	95	100
2.36 mm	117.61	23.52	52.16	47.84	80	100
1.18 mm	82.73	16.55	68.71	31.29	50	85
600 µm	75.83	15.17	83.88	16.12	25	60
300 µm	52.74	10.55	94.43	5.57	5	30
150 µm	18.93	3.79	98.22	1.78	0	10
75 µm	8.24	1.65	99.87	0.13	0	0
Pan	0.5	0.1	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 4.27

5.5.Experimental Result of samples affected by leaves and flora (MRL)

Part 1.

River quarry: MR Supply point (code): MRL points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRL_1	Silt content	%	7.75	Jar test
		Bulking of sand	%	18.15	Jar test
		Unit weight	Kg/m^3	1521.89	Loose method
		Percentage void	%	16.88	Effect of compaction
		Specific gravity	-	2.67	ACI
		Absorption	%	3.93	ACI
		Organic impurity	Number	1	Color chart
2	MRL_2	Silt content	%	10.55	Jar test
		Bulking of sand	%	20.05	Jar test
		Unit weight	Kg/m^3	1497.84	Loose method
		Percentage void	%	17.54	Effect of compaction
		Specific gravity	-	2.54	ACI
		Absorption	%	4.95	ACI
		Organic impurity	Number	1	Color chart
3	MRL_3	Silt content	%	12.5	Jar test
		Bulking of sand	%	21.23	Jar test
		Unit weight	Kg/m^3	1396.77	Loose method
		Percentage void	%	17.81	Effect of compaction
		Specific gravity	-	2.58	ACI
		Absorption	%	6.15	ACI
		Organic impurity	Number	2	Color chart

Part 2. Concrete compressive strength

⇨ Mersa River samples affected by leaves and flora (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13.1	ACI mix design method for C-25
14^{th}	19.5	ACI mix design method for C-25
28^{th}	23.4	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Mersa River samples affected by leaves and flora 1 (MRL_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.16	0.43	0.43	99.57	100	100
4.75 mm	44.21	8.84	9.27	90.73	95	100
2.36 mm	32.86	6.57	15.84	84.16	80	100
1.18 mm	72.64	14.53	30.37	69.63	50	85
600 µm	99.64	19.93	50.3	49.7	25	60
300 µm	130.87	26.17	76.47	23.53	5	30
150 µm	78.64	15.73	92.2	7.8	0	10
75 µm	32.89	6.58	98.78	1.22	0	0
Pan	5.68	1.14	99.92	0.08		
Total						

Fineness Modulus of fine aggregate = 2.75

⇨ Mersa River samples affected by leaves and flora 2 (MRL_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.51	0.5	0.5	99.5	100	100
4.75 mm	42.31	8.46	8.96	91.04	95	100
2.36 mm	29.94	5.99	14.95	85.05	80	100
1.18 mm	75.21	15.04	29.99	70.01	50	85
600 µm	105.64	21.13	51.12	48.88	25	60
300 µm	145.73	29.15	80.27	19.73	5	30
150 µm	75.16	15.03	95.3	4.7	0	10
75 µm	20.64	4.13	99.43	0.57	0	0
Pan	2.71	0.54	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 2.81

⇨ Mersa River samples affected by leaves and flora 3 (MRL_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.17	0.23	0.23	99.77	100	100
4.75 mm	24.94	4.99	5.22	94.78	95	100
2.36 mm	67.25	13.45	18.67	81.33	80	100
1.18 mm	76.54	15.31	33.98	66.02	50	85
600 µm	91.83	18.37	52.35	47.65	25	60
300 µm	140.25	28.05	80.4	19.6	5	30
150 µm	66.34	13.27	93.67	6.33	0	10
75 µm	29.03	5.81	99.48	0.52	0	0
Pan	2.05	0.41	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 2.85

5.6.Experimental Result of samples affected by production treatment and storage (MRP)
Part 1.
River quarry: MR Supply point (code): MRP points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	MRP_1	Silt content	%	0	Jar test
		Bulking of sand	%	9.05	Jar test
		Unit weight	Kg/m^3	1834.11	Loose method
		Percentage void	%	8.45	Effect of compaction
		Specific gravity	-	3.15	ACI
		Absorption	%	2.05	ACI
		Organic impurity	Number	1	Color chart
2	MRP_2	Silt content	%	0.45	Jar test
		Bulking of sand	%	10.25	Jar test
		Unit weight	Kg/m^3	1785.25	Loose method
		Percentage void	%	10.47	Effect of compaction
		Specific gravity	-	3.0	ACI
		Absorption	%	2.14	ACI
		Organic impurity	Number	1	Color chart
3	MRP_3	Silt content	%	0.35	Jar test
		Bulking of sand	%	10.0	Jar test
		Unit weight	Kg/m^3	1749.64	Loose method
		Percentage void	%	11.07	Effect of compaction
		Specific gravity	-	2.99	ACI
		Absorption	%	2.35	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Mersa River samples affected by production treatment and storage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7th	23.6	ACI mix design method for C-25
14th	30.4	ACI mix design method for C-25
28th	35.6	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Mersa River samples affected by production treatment and storage; MRP (similar grading was used in all points)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	12.5	2.5	2.5	97.5	95	100
2.36 mm	37.5	7.5	10	90	80	100
1.18 mm	112.5	22.5	32.5	67.5	50	85
600 µm	125	25	57.5	42.5	25	60
300 µm	125	25	82.5	17.5	5	30
150 µm	62.5	12.5	95	5	0	10
75 µm	25	5	100	0	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 2.8

Appendix 6: Laboratory test results of Tikurwuha River Sand

6.1.Experimental Result of Tikurwuha controlled samples (TKC)

Part 1.

River quarry: TK Supply point (code): TKC points

No.	Supply points (by code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKC_1	Silt content	%	4.5	Jar test
		Bulking of sand	%	16.5	Jar test
		Unit weight	Kg/m^3	1655.07	Loose method
		Percentage void	%	15.45	Effect of compaction
		Specific gravity	-	2.87	ACI
		Absorption	%	3.5	ACI
		Organic impurity	Number	1	Color chart
2	TKC_2	Silt content	%	1.17	Jar test
		Bulking of sand	%	17.64	Jar test
		Unit weight	Kg/m^3	1709.14	Loose method
		Percentage void	%	17.99	Effect of compaction
		Specific gravity	-	2.87	ACI
		Absorption	%	3.97	ACI
		Organic impurity	Number	1	Color chart
3	TKC_3	Silt content	%	3.28	Jar test
		Bulking of sand	%	20	Jar test
		Unit weight	Kg/m^3	1705.61	Loose method
		Percentage void	%	18.4	Effect of compaction
		Specific gravity	-	2.62	ACI
		Absorption	%	5.93	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Tikurwuha River Controlled sample (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	15.9	ACI mix design method for C-25
14^{th}	22.7	ACI mix design method for C-25
28^{th}	27.6	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Tikurwuha River Controlled sample 1 (TKC_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.63	0.53	0.53	99.47	100	100
4.75 mm	62.45	12.49	13.02	86.98	95	100
2.36 mm	134.27	26.85	39.87	60.13	80	100
1.18 mm	107.36	21.45	61.32	38.68	50	85
600 µm	85.29	17.06	78.38	11.62	25	60
300 µm	71.81	14.36	92.74	7.26	5	30
150 µm	21.95	4.39	97.13	2.87	0	10
75 µm	11.25	2.25	99.38	0.62	0	0
Pan	2.53	0.51	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 3.83

⇨ Tikurwuha River Controlled sample 2 (TKC_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	11.32	2.26	2.26	97.74	100	100
4.75 mm	97.21	19.44	21.7	78.3	95	100
2.36 mm	124.91	24.98	46.68	53.32	80	100
1.18 mm	98.08	19.62	66.3	33.7	50	85
600 µm	77.3	15.46	81.76	18.24	25	60
300 µm	69.5	13.9	95.66	4.34	5	30
150 µm	19.4	3.88	99.54	0.46	0	10
75 µm	2.07	0.41	99.95	0.05	0	0
Pan	0	0	99.95	0.05		
Total						

Fineness Modulus of fine aggregate = 4.14

⇨ Tikurwuha River Controlled sample 3 (TKC_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	12.72	2.54	2.54	97.46	100	100
4.75 mm	127.9	25.58	28.12	71.88	95	100
2.36 mm	114.64	22.93	51.05	48.95	80	100
1.18 mm	62.11	12.42	63.47	36.53	50	85
600 µm	91.94	18.39	81.86	18.14	25	60
300 µm	72.04	14.41	96.27	3.73	5	30
150 µm	11.34	2.27	98.54	1.46	0	10
75 µm	5.19	1.04	99.58	0.42	0	0
Pan	1.51	0.3	99.88	0.12		
Total						

Fineness Modulus of fine aggregate = 4.22

6.2.Experimental Result of samples affected by human and animal (TKH)

Part 1.

River quarry: TK Supply point (code) TKH points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKH_1	Silt content	%	12	Jar test
		Bulking of sand	%	22.55	Jar test
		Unit weight	Kg/m^3	1711.3	Loose method
		Percentage void	%	20.13	Effect of compaction
		Specific gravity	-	2.68	ACI
		Absorption	%	5.15	ACI
		Organic impurity	Number	2	Color chart
2	TKH_2	Silt content	%	8.585	Jar test
		Bulking of sand	%	20.55	Jar test
		Unit weight	Kg/m^3	1619.61	Loose method
		Percentage void	%	18.73	Effect of compaction
		Specific gravity	-	2.81	ACI
		Absorption	%	4.975	ACI
		Organic impurity	Number	1	Color chart
3	TKH_3	Silt content	%	6.25	Jar test
		Bulking of sand	%	20.55	Jar test
		Unit weight	Kg/m^3	1534.18	Loose method
		Percentage void	%	19.84	Effect of compaction
		Specific gravity	-	2.71	ACI
		Absorption	%	5.10	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Tikurwuha River samples affected by human and animal (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	14.5	ACI mix design method for C-25
14^{th}	20.7	ACI mix design method for C-25
28^{th}	24.5	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Tikurwuha River samples affected by human and animal 1 (TKH_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.5	0.1	0.1	99.9	100	100
4.75 mm	1.3	0.26	0.36	99.64	95	100
2.36 mm	61.37	12.27	12.63	87.37	80	100
1.18 mm	68.29	13.66	26.29	73.81	50	85
600 µm	132.84	26.57	52.86	47.21	25	60
300 µm	124.64	24.93	77.79	22.21	5	30
150 µm	73.58	14.72	92.51	7.49	0	10
75 µm	34.26	6.85	99.36	0.64	0	0
Pan	2.65	0.53	99.89	0.11		
Total						

Fineness Modulus of fine aggregate = 2.63

⇨ Tikurwuha River samples affected by human and animal 2 (TKH_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	0	0	0	100	95	100
2.36 mm	51.55	10.31	10.31	89.69	80	100
1.18 mm	65.04	13.01	23.32	76.68	50	85
600 µm	142.87	28.57	51.89	48.11	25	60
300 µm	117.34	23.47	75.36	24.64	5	30
150 µm	85.06	17.01	92.37	7.63	0	10
75 µm	34.27	6.85	99.22	0.78	0	0
Pan	3.47	0.69	99.91	0.09		
Total						

Fineness Modulus of fine aggregate = 2.53

⇨ Tikurwuha River samples affected by human and animal 3 (TKH_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	11.87	2.37	2.37	97.63	100	100
4.75 mm	2.67	0.53	2.9	97.1	95	100
2.36 mm	79.14	15.83	18.73	81.27	80	100
1.18 mm	62.81	12.56	31.29	68.71	50	85
600 µm	151.97	30.39	61.68	38.32	25	60
300 µm	97.25	19.45	81.13	18.87	5	30
150 µm	75.94	15.19	96.32	3.68	0	10
75 µm	14.31	2.86	99.18	0.82	0	0
Pan	3.47	0.69	99.87	0.13		
Total						

Fineness Modulus of fine aggregate = 2.94

6.3.Experimental Result samples affected by detergent and sewage (TKD)
Part 1.
River quarry: TK   Supply point (code): TKD

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKD_1	Silt content	%	11.23	Jar test
		Bulking of sand	%	19.85	Jar test
		Unit weight	Kg/m^3	1756.5	Loose method
		Percentage void	%	15.21	Effect of compaction
		Specific gravity	-	2.64	ACI
		Absorption	%	4.43	ACI
		Organic impurity	Number	4	Color chart
2	TKD_2	Silt content	%	7.13	Jar test
		Bulking of sand	%	20.75	Jar test
		Unit weight	Kg/m^3	1689.14	Loose method
		Percentage void	%	15.56	Effect of compaction
		Specific gravity	-	2.68	ACI
		Absorption	%	4.55	ACI
		Organic impurity	Number	3	Color chart
3	TKD_3	Silt content	%	8.33	Jar test
		Bulking of sand	%	17.54	Jar test
		Unit weight	Kg/m^3	1657.63	Loose method
		Percentage void	%	16.49	Effect of compaction
		Specific gravity	-	2.70	ACI
		Absorption	%	5.12	ACI
		Organic impurity	Number	4	Color chart

Part 2. Concrete compressive strength
⇨ Tikurwuha River samples affected by detergent and sewage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	15.2	ACI mix design method for C-25
14^{th}	21.133	ACI mix design method for C-25
28^{th}	22.9	ACI mix design method for C-25

Part 3. Sieve Analysis
⇨ Tikurwuha River samples affected by detergent and sewage 1 (TKD_1)
Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.4	0.28	0.28	99.72	100	100
4.75 mm	35.62	7.12	7.4	92.6	95	100
2.36 mm	51.89	10.38	17.73	82.27	80	100
1.18 mm	87.61	17.52	35.3	64.7	50	85
600 µm	113.81	22.76	58.06	41.94	25	60
300 µm	124.3	24.86	82.92	17.08	5	30
150 µm	62.13	12.43	95.35	4.65	0	10
75 µm	19.85	3.97	99.32	0.35	0	0
Pan	2.8	0.56	99.88	0.12		
Total						

Fineness Modulus of fine aggregate = 3.32

⇨ Tikurwuha River samples affected by detergent and sewage 2 (TKD_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.91	0.18	0.18	99.82	100	100
4.75 mm	24.97	4.99	5.17	94.83	95	100
2.36 mm	48.21	9.64	14.81	85.19	80	100
1.18 mm	101.43	20.29	35.1	64.9	50	85
600 µm	120.41	24.1	59.2	40.8	25	60
300 µm	122.07	24.41	83.61	16.39	5	30
150 µm	62.75	12.55	96.16	3.84	0	10
75 µm	15.24	3.05	99.21	0.79	0	0
Pan	3.62	0.72	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 2.94

⇨ Tikurwuha River samples affected by detergent and sewage 3 (TKD_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	12.67	2.53	2.53	97.47	100	100
4.75 mm	38.41	7.68	10.21	89.79	95	100
2.36 mm	58.64	11.73	21.94	78.06	80	100
1.18 mm	92.17	18.43	40.37	59.63	50	85
600 µm	123.06	24.61	64.98	35.02	25	60
300 µm	93.5	18.7	83.68	16.32	5	30
150 µm	56.49	11.3	94.98	5.02	0	10
75 µm	21.65	4.33	99.31	0.69	0	0
Pan	2.71	0.54	99.85	0.15		
Total						

Fineness Modulus of fine aggregate = 3.19

6.4.Experimental Result of samples affected by water flow of the river (TKW)
Part 1.
River quarry: TK Supply point (code): TKW points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKW_1	Silt content	%	21.5	Jar test
		Bulking of sand	%	22.95	Jar test
		Unit weight	Kg/m^3	1345.78	Loose method
		Percentage void	%	23.21	Effect of compaction
		Specific gravity	-	2.51	ACI
		Absorption	%	6.15	ACI
		Organic impurity	Number	2	Color chart
2	TKW_2	Silt content	%	20.5	Jar test
		Bulking of sand	%	19.95	Jar test
		Unit weight	Kg/m^3	1513.14	Loose method
		Percentage void	%	20.12	Effect of compaction
		Specific gravity	-	2.68	ACI
		Absorption	%	5.35	ACI
		Organic impurity	Number	2	Color chart
3	TKW_3	Silt content	%	12.45	Jar test
		Bulking of sand	%	19.35	Jar test
		Unit weight	Kg/m^3	1664.55	Loose method
		Percentage void	%	17.45	Loose method
		Specific gravity	-	2.71	ACI
		Absorption	%	5.35	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Tikurwuha River samples affected by water flow of the river (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	13.3	ACI mix design method for C-25
14^{th}	18.3	ACI mix design method for C-25
28^{th}	21.6	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Tikurwuha River samples affected by water flow of the river 1 (TKW_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	6.1	1.22	1.22	98.78	100	100
4.75 mm	86.42	17.28	18.5	81.5	95	100
2.36 mm	139.21	27.84	46.34	53.66	80	100
1.18 mm	118.74	23.75	70.09	29.91	50	85
600 µm	58.42	11.68	81.77	18.23	25	60
300 µm	51.99	10.4	92.17	7.83	5	30
150 µm	29.26	5.85	98.02	1.98	0	10
75 µm	8.63	1.73	99.75	0.25	0	0
Pan	1.08	0.22	99.97	0.03		
Total						

Fineness Modulus of fine aggregate = 4.08

⇨ Tikurwuha River samples affected by water flow of the river 2 (TKW_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.94	0.39	0.39	99.61	100	100
4.75 mm	85.71	17.14	17.53	82.47	95	100
2.36 mm	103.27	20.65	38.18	61.82	80	100
1.18 mm	113.03	22.61	60.79	39.21	50	85
600 µm	92.56	18.51	79.3	20.7	25	60
300 µm	48.21	9.64	88.94	11.06	5	30
150 µm	47.98	9.6	98.54	1.46	0	10
75 µm	3.86	0.77	99.31	0.69	0	0
Pan	3.11	0.62	99.93	0.07		
Total						

Fineness Modulus of fine aggregate = 3.84

⇨ Tikurwuha River samples affected by water flow of the river 3 (TKW_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.84	0.17	0.17	99.83	100	100
4.75 mm	1.92	0.38	0.55	99.45	95	100
2.36 mm	21.74	4.38	4.93	95.07	80	100
1.18 mm	42.68	8.54	13.47	86.53	50	85
600 µm	81.34	16.27	29.74	70.26	25	60
300 µm	178.14	35.63	65.37	34.63	5	30
150 µm	92.7	18.54	83.91	16.09	0	10
75 µm	62.58	12.52	96.43	3.57	0	0
Pan	17.8	3.56	99.99	0.01		
Total						

Fineness Modulus of fine aggregate = 1.98

6.5.Experimental Result of samples affected by leaves and flora (TKL)

Part 1.

River quarry: TK Supply point (code): TKL points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKL_1	Silt content	%	16.3	Jar test
		Bulking of sand	%	20.13	Jar test
		Unit weight	Kg/m^3	1297.23	Loose method
		Percentage void	%	17.77	Effect of compaction
		Specific gravity	-	2.59	ACI
		Absorption	%	3.85	ACI
		Organic impurity	Number	2	Color chart
2	TKL_2	Silt content	%	7.55	Jar test
		Bulking of sand	%	19.23	Jar test
		Unit weight	Kg/m^3	1463.14	Loose method
		Percentage void	%	17.99	Effect of compaction
		Specific gravity	-	2.68	ACI
		Absorption	%	4.25	ACI
		Organic impurity	Number	1	Color chart
3	TKL_3	Silt content	%	6.87	Jar test
		Bulking of sand	%	21.37	Jar test
		Unit weight	Kg/m^3	1545.78	Loose method
		Percentage void	%	16.84	Loose method
		Specific gravity	-	2.62	ACI
		Absorption	%	4.31	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Tikurwuha River samples affected by leaves and flora 1 (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	14.7	ACI mix design method for C-25
14^{th}	20.1	ACI mix design method for C-25
28^{th}	23.6	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Tikurwuha River samples affected by leaves and flora 1 (TKL_1)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	1.52	0.3	0.3	99.7	100	100
4.75 mm	10.2	2.04	2.34	97.66	95	100
2.36 mm	23.87	4.77	7.11	92.89	80	100
1.18 mm	72.19	14.44	21.55	78.45	50	85
600 µm	112.17	22.43	43.98	56.02	25	60
300 µm	157.55	31.51	75.49	24.51	5	30
150 µm	80.24	16.05	91.54	8.46	0	10
75 µm	35.97	7.19	98.73	1.27	0	0
Pan	5.94	1.19	99.92	0.08		
Total						

Fineness Modulus of fine aggregate = 2.42

⇨ Tikurwuha River samples affected by leaves and flora 2 (TKL_2)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0.84	0.17	0.17	99.83	100	100
4.75 mm	32.91	6.58	6.75	93.25	95	100
2.36 mm	86.21	17.24	23.99	76.01	80	100
1.18 mm	42.96	8.59	32.58	67.42	50	85
600 µm	98.46	19.69	52.27	47.73	25	60
300 µm	111.13	22.23	74.5	25.5	5	30
150 µm	62.86	12.57	87.07	12.93	0	10
75 µm	52.8	10.56	97.63	2.37	0	0
Pan	11.82	2.36	99.99	0.01		
Total						

Fineness Modulus of fine aggregate = 2.77

⇨ Tikurwuha River samples affected by leaves and flora 3 (TKL_3)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	2.11	0.42	0.42	99.58	100	100
4.75 mm	45.27	9.05	9.47	90.53	95	100
2.36 mm	112.93	22.59	32.06	67.94	80	100
1.18 mm	84.33	16.87	48.93	51.07	50	85
600 µm	78.35	15.67	64.6	35.4	25	60
300 µm	79.07	15.81	80.41	19.59	5	30
150 µm	50.86	10.17	90.58	9.42	0	10
75 µm	43.38	8.68	99.26	0.74	0	0
Pan	2.92	0.58	99.84	0.16		
Total						

Fineness Modulus of fine aggregate = 3.27

6.6.Experimental Result of samples affected by production treatment and storage (TKP)
Part 1.
River quarry: TK   Supply point (code): TKP points

No.	Supply points (code)	Type of experiment	Experimental results		
			Unit	Result	Methods used
1	TKP_1	Silt content	%	0.25	Jar test
		Bulking of sand	%	11.5	Jar test
		Unit weight	Kg/m^3	1819.25	Loose method
		Percentage void	%	13.94	Effect of compaction
		Specific gravity	-	2.99	ACI
		Absorption	%	2.43	ACI
		Organic impurity	Number	1	Color chart
2	TKP_2	Silt content	%	0.0	Jar test
		Bulking of sand	%	10.85	Jar test
		Unit weight	Kg/m^3	1803.66	Loose method
		Percentage void	%	9.95	Effect of compaction
		Specific gravity	-	3.05	ACI
		Absorption	%	2.43	ACI
		Organic impurity	Number	1	Color chart
3	TKP_3	Silt content	%	0.0	Jar test
		Bulking of sand	%	10.99	Jar test
		Unit weight	Kg/m^3	1787.98	Loose method
		Percentage void	%	8.87	Effect of compaction
		Specific gravity	-	3.13	ACI
		Absorption	%	2.51	ACI
		Organic impurity	Number	1	Color chart

Part 2. Concrete compressive strength

⇨ Tikurwuha River samples affected by production treatment and storage (mix of three samples)

Day of measurement	Compressive strength (MPa)	Description
7^{th}	22.9	ACI mix design method for C-25
14^{th}	32	ACI mix design method for C-25
28^{th}	38	ACI mix design method for C-25

Part 3. Sieve Analysis

⇨ Tikurwuha River samples affected by production treatment and storage; TKP (similar grading was used in all points)

Weight of sample taken: 500gm

Sieve size	Weight retained(gm.)	% Weight retained	Cumulative % of Wt. retained	Cumulative % Passing	Lower limit	Upper limit
9.5 mm	0	0	0	100	100	100
4.75 mm	12.5	2.5	2.5	97.5	95	100
2.36 mm	37.5	7.5	10	90	80	100
1.18 mm	112.5	22.5	32.5	67.5	50	85
600 µm	125	25	57.5	42.5	25	60
300 µm	125	25	82.5	17.5	5	30
150 µm	62.5	12.5	95	5	0	10
75 µm	25	5	100	0	0	0
Pan	0	0				
Total						

Fineness Modulus of fine aggregate = 2.8

Appendix 7, three-point GPS reading of sand source rivers

No.	River name	Reading points	Coordinate		
			X	Y	Z
1	Alawuha	Point 1	574208	1315457	1412
		Point 2	574051	1315353	1416
		Point 3	573777	1315211	1419
2	Golina	Point 1	568053	1334040	1469
		Point 2	567893	1334071	1477
		Point 3	567656	1334102	1475
3	Hormat	Point 1	568698	1339311	1455
		Point 2	568501	1339301	1453
		Point 3	568279	1339406	1459
4	Mersa	Point 1	571636	1290836	1606
		Point 2	571256	1290912	1610
		Point 3	571169	1291099	1629
5	Tikurwuha	Point 1	561352	1308707	1702
		Point 2	560600	1307788	1734
		Point 3	560522	1307554	1750