



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
(MENG PROGRAM IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT)

**HANDLING OF AGGREGATES IN THE
ETHIOPIAN CONSTRUCTION INDUSTRY: THE CASE OF
ADDIS ABABA**

**A PROJECT SUBMITTED TO THE DEPARTMENT OF CIVIL AND
ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT FOR
MASTERS OF ENGINEERING IN CONSTRUCTION TECHNOLOGY AND
MANAGEMENT**

Submitted to:
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Addis Ababa

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ABSTRACT

Aggregate handling is one of the major tasks in the construction industry. It plays vital roles in the effectiveness and efficiency of the construction industry. Hence, the study investigated the problems of aggregate handling in the construction industry in Addis Ababa. It also investigated the causes of unsafe handling of aggregates and forward recommendations to those who are responsible in the construction technology and management. The researcher selected three aggregate production plants, two concrete batching plants and four construction sites located in Addis Ababa based on convenience and data availability. Two methods of data collection – observation and key informant interview – were used. The concerned people were interviewed and observations were made on those selected sections of the industry and interviews were conducted to investigate the real situations of aggregates handling. Findings from the interview and observation showed that there are huge gaps in the handling of aggregates in construction industry. Contractors are responsible and liable for the supply and proper handling of aggregates in the construction projects as per required standards. However, neither the consultant nor the concerned regulatory bodies enforced the contractors to apply the right handling procedures. Complete and proper handling mechanisms of aggregates are not properly implemented in the construction industry. Consultants had not established well detailed safety mechanisms in handling of construction materials in the construction projects while preparing binding contract documents. In the cases examined, expert teams are seldom available to implement and control the proper aggregate handling mechanisms. Contractors do not give special attention in handling of aggregates either from the source or in the construction sites by providing relevant training for workers responsible in handling aggregates. The workers employed in construction projects are largely casual laborers with limited training in handling of aggregates. This resulted in production of poor quality of concrete that will eventually affect the quality of the construction projects. The government regulatory body, the Ministry of Urban Development and Construction, should develop and implement a quality control mechanism on aggregate handling. The consultants should also give proper emphasis to aggregate handling when preparing contract documents and verify the implementation of the provisions about aggregate handling.

Key words: Aggregates, aggregate handling, construction industry, construction technology and management, Addis Ababa.

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CHAPTER 1: INTRODUCTION

1.1 Background of the Project

Concrete is the most widely used man-made construction material and it is second to water as the most utilized substance in the world. It is produced by mixing cementitious materials, water and aggregates (and sometimes admixtures) in some proportions. When the mixture is placed and cured, it forms a rock-like mass known as concrete, which is a hard substance. The hardened concrete may also be considered as an artificial stone in which the voids of larger particles are filled by the smaller particles and the voids of fine aggregates are filled with cement. The strength, durability and other characteristics of concrete depends up on the properties of its ingredients, the proportions of mix, the method of compaction and other controls during placing, compaction and curing. The advances in concrete technology have paved the way to make use of locally available materials by judicious mix proportioning and proper workmanship so as to produce concrete satisfying performance requirements. Producing strong, durable and uniform concrete requires careful control of the processes of concrete production [1].

Among the ingredients, aggregates constitute about 75 percent of the volume of concrete. Thus, its careful handling is extremely important. Aggregates should therefore meet certain standards if the concrete is to be workable, strong, durable, and economical. The aggregates must be of proper shape (either rounded or cubical), clean, hard, strong, and well graded. It should possess chemical stability and, in many cases exhibit abrasion resistance and resistance to freezing and thawing [1].

The production of aggregates in the world is estimated at about 16.5 billion tons per annum that worth 70 billion U.S Dollars. This makes aggregate production one of the most important mining industries in the world. Aggregate is a high bulk but relatively low cost construction materials. Its market value is determined from being located near to the construction site. Transporting aggregates long distances increase its cost. Therefore, the operation of aggregate production is commonly located near to settlement centers [5].

Material selection has a great role in achieving satisfactory product. It is not always, easily recognized that methods adopted for handling and storing of construction materials are equally

important. In addition, the method of production by the material producers and the means of selecting materials from the source are not usually given proper attention. The manufacturers and suppliers might go to long process in providing products that fit with the standards [Johnson, 1981 cited in 2].

1.2 Statement of the problem

Handling of aggregates in the construction industries is the necessary issue that should be considered to keep the aggregates fit for the purpose. Observations of the researcher also showed that there is mishandling of aggregates in the construction industry in the city of Addis Ababa and aggregates were damped here and there specially in construction sites. Proper handling of aggregates is well documented to determine the quality of construction projects. Some researchers conducted studies on handling and standardization of aggregates in Ethiopia [2, 9 and 11]. Given its importance, more studies need to be conducted in the area by bringing some site specific cases. This has necessitated the researcher to take up the issues of aggregate handling from its source, in the aggregate production plants, concrete batching plants, construction sites etcetera. This study is, therefore, intended to investigate the practice of handling of aggregates in construction industries in the city of Addis Ababa. It, therefore, tried to answer the following questions:

1. What are the practices of aggregates handling in construction industries in Addis Ababa?
2. To what extent do the concerned government regulatory bodies engaged in the control of proper handling of aggregates?
3. What measures should be taken to have proper aggregates handling in the construction industry?

1.3 Objectives of the Study

1.3.1 General objective

The main objective of this study is to investigate the practices and challenges of handling of aggregates in construction industries in the city of Addis Ababa.

Specific objectives

The specific objectives of the project are:

1. To identify the practices of handling of aggregates in construction industries in Addis Ababa.
2. To investigate the involvement of government institutions in regulating the handling of aggregates in Addis Ababa.
3. To identify the measures to be taken in developing proper aggregates handling in the construction industry.

CHAPTER 2: LITERATURE REVIEW

2.1 An Overview of Aggregates

In the construction technology, resource planning and management is one of the most important parameter for competitiveness and profitability. The management of construction materials is the task of resource management and it is also an important element in project planning and controlling. The cost of materials in construction projects accounts for more than 40% of the project cost. Therefore, a small saving in material cost has a significant role in the industry. A research conducted in Ethiopia had shown that 57% of the total budget allocated for construction is material cost [2]. As per [13], building materials account for 50–80% of the total value of construction. Thus, it is very important to ensure that construction materials are available at affordable prices. In most developing countries, however, the costs of construction materials are very high, and their availability is scarce.

Aggregates generally constitute 65–75% of the volume of concrete. Hence due consideration should be given to the selection and proportioning of aggregates. The aggregates are used in production of concrete for normal structural purposes. The term mineral filler is often used to describe aggregates used for making concrete. Aggregates are not truly inert and their physical, thermal and chemical properties influence the quality of concrete [3]. Aggregates are produced either naturally or artificially. It can also be crushed or uncrushed, stone, gravel, sand, blast furnace, slag, furnace clinker etcetera. They can be classified as coarse aggregate, fine aggregate or the combination of the two [13].

Despite the various ways of classifications, three important criteria should be applied in the selection of aggregates. First, the material selected as aggregate should facilitate the workability of fresh concrete. This is because the size and gradation of the aggregate has impact on the workability of fresh concrete. Second, the strength and durability of aggregates should be taken into account during the selection process. In other words, aggregates should not contain impurities, and it should resist weathering process. Lastly, the selection of aggregates should be economical. When aggregates are selected from local and easily accessible quarry, the cost is substantially reduced. It has to be, however, well graded in order to minimize paste. Aggregates

provide relatively cheap filler and it is advisable to use as much aggregates as possible in a given amount of paste will bind together. This enables to cut down unnecessary costs incurred for cement. In addition to being relatively cheap fillers, the aggregates reduce the change in volume resulting from the setting and hardening process and from moisture change in the paste [3].

2.2 Fundamental Issues in Aggregates

Given that aggregate as the major component of concrete, the following fundamental issues should be understood.

- 1. Function of Aggregates:** Aggregates have three principal functions. (i) They provide relatively cheaper filler for cementing material; (ii) they provide a mass of particles that resist the actions of applied loads and weather, abrasion, percolation of moisture; and (iii) they reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste [Mikyias, 1987 cited in 2].
- 2. Properties of Aggregates:** Aggregates have physical properties (such as specific gravity, shape, density and porosity), thermal and chemical properties. These properties are attributed to the parent rock and to the mode of production. It is, therefore, very important to give due consideration to the source and production of aggregates [2]. The changing of the properties of aggregates by keeping the grading limit, cement content and silt content will result in a significant increase in compressive strength of the concrete. This shows that the quality of aggregate is one of the important factors for the change in properties of concrete [9]. The thermal properties of aggregates affect the durability and other qualities of concrete. The principal thermal properties of aggregates are: coefficient of thermal expansion, specific heat and thermal conductivity. The coefficient of thermal expansion of the concrete is directly proportional to thermal expansion of aggregates. If the coefficient of expansion of a coarse aggregate and the cement paste differ too much, a change in temperature may introduce differential movement, which may break the bond between the aggregates and the paste. If the coefficients of the two materials differ by more than 5.4×10^{-6} per $^{\circ}\text{C}$, the durability of concrete subjected to freezing and thawing may be affected. The specific heat of aggregate is a measure of its heat capacity whereas the thermal conductivity is the ability of the aggregate to conduct heat. These properties

of the aggregate influence the specific heat and thermal conductivity of the concrete, and are important in the case of mass concrete [1].

3. **Classification of Aggregates:** Aggregates are classified in different ways based on the source, content of chemicals, weight, size and/or mode of production. However, the method of classification widely used in concrete works is based on the aggregate size. Aggregates bigger than 4.75 mm in diameter are classified as coarse aggregate and those smaller than 4.75 mm are classified as fine aggregates. In some countries there exist all-in aggregate – an aggregate composed of both fine and coarse aggregate [3].
4. **Harmful Substances in Aggregates:** There are three broad categories of deleterious substances that may be found in aggregates. These are impurities that interfere with the process of hydration of cement, coatings preventing the development of good bond between aggregates and cement paste, and certain individual particles that are weak or unsound. In addition to the harmful effects of impurities, effects resulting from the development of chemical reactions between the aggregates and the cement paste affect the quality of structure. For example, aggregates containing sulfate or chloride will cause corrosion in the reinforced concrete. The salt content in the sand will also absorb moisture from the air and cause efflorescence on the surface of the concrete. As a remedial action, the sand has to be washed before use [4]. The dust content of aggregates is also given less attention by aggregate producers that ultimately affect the quality of concrete production [9]. The engineer has to take handful of aggregates and examine small balls of clay, soft spongy and flaky stones, pieces of bricks, soft shale and crumbly bits of sandstone. If the expert investigated pieces of weak stone or piece of clay from a few handfuls of aggregates, s/he should request the contractor to check the product from the source in order to get better supplies. It is also important to check the for alkali-silica reaction of the aggregates which can potentially cause expansion and disruption of the concrete [10]. When aggregates are exposed to changes in temperature and weather, it tends to disintegrate into smaller particles that affect the soundness property of aggregates. The maximum limit of the deleterious materials in aggregates is shown in percentage in Table 2.1.

Table 2.1 Tolerable levels of deleterious materials in aggregates (%)

Substance	Fine Aggregate		Coarse Aggregate	
	Uncrushed	crushed	Uncrushed	crushed
Coal and lignite	1	1	1	1
Clay lumps	1	1	1	1
Soft particles	0	0	3	0
Materials passing 75micron IS sieve	3	15	3	1
Shale	1	-	0	0
Sum of materials	5	-	5	5

Source [12:5]

- 5. Soundness of Aggregate:** The soundness of aggregates is the ability of aggregates to resist excessive changes in volume due to changes in environmental conditions such as freezing and thawing, thermal changes and alternating wetting and drying. The aggregate is said to be unsound when the volume changes result in the deterioration of the concrete. This may appear in the form of local scaling to extensive surface cracking or to disintegration over a considerable depth [1].

2.3 Production of Aggregates

2.3.1 General

Aggregates take three quarters of the volume of concrete, and its quality of production is considerably important. The quality of aggregates determines not only the strength of concrete but also the durability and structural performances of concrete. Aggregates are originally viewed as inert and inexpensive materials. In reality, however, aggregates are not inert because its physical, thermal and chemical properties affect the quality of concrete. The natural aggregates are formed as a result of the processes of weathering and abrasion or through crushing a large parent mass. This shows that the properties of aggregates depend on the properties of the parent rock [4].

Different geological locations result in diverse types of aggregates. All rocks do not necessarily provide aggregates with similar qualities. Good quality aggregates are hard, tough and do not easily break down into pieces. Selection of a quarry should be based on the suitability of the parent material, proximity to settlement areas, transport costs, the existing and planned land use the quarry's location and its impact on the environment. 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 different quality parameters discussed above [2].

Excavating crushed stone, sand and gravel depends on the geological characteristics, and the extent and thickness of the deposit. In the United States of America, open pit mining and quarrying methods are the common sources of aggregates. Quarrying and mining stones require drilling and blasting. Then, it can be extracted by using shovels, bulldozers, and drag lines. Both sand and gravel deposits are commonly extracted with conventional earth-moving equipments such as bulldozers, front end loaders and tractor scrapers. But it may be excavated from streams or water-filled pits with draglines or from barges that use the hydraulic or ladder dredges. Processing of quarried rock and large gravel requires crushing, which depends on the size of the final product. After crushing, the aggregate is moved by conveyors to bins or is stockpiled by size. Finally, the aggregate is loaded on trucks, railcars, barges or freighters [5].

2.3.2 Production of Coarse Aggregate

It is important to control the production processes of coarse aggregates to be delivered, stored, and batched using separate single sizes rather than a graded coarse aggregate [Blackledge, 2002 cited in 2]. Production of coarse aggregates includes blasting of rock, transporting of the crushed rock by conveyor to the crushing plant, and adjusting the crusher so as to give a range of different sizes by passing the crushed rock through a set of sieves [Mikyias, 1987 cited in 2]. To produce a uniform concrete throughout different batching, the coarse aggregate is separated into several size fractions. A hard ground made of concrete shall be prepared for bulk storage and a space or dwarf walls should be placed in order to keep different materials and sizes apart. The stockpiles should be arranged in a horizontal manner with a gentle slope but not by end dumping method [Taylor, 1977 cited in 2].

2.3.3 Production of Fine Aggregate

Sand is a material that mainly passes through a 5.00mm BS test sieve. Sand can be classified as natural sand, crushed stone sand, crushed gravel sand or a combination of any of these. They should be hard, durable, clean and free from adherent coatings like and in clay pallet form. It should not contain harmful substances like iron pyrites, salts, coal, other organic impurities, mica, and shale, flaky or elongated particles. It consists of a uniformly distributed particle of different sizes. The grading of sands shall be determined by the method of sieve analysis. When testing is carried out in compliance with the British Standards (BS), two independent test results are used to determine the grade of the sand [14]. There is no testing method and acceptable range limits to determine the clay content of sand as adherent coating substance or as lumps in aggregate. However, if a sample of sand is rubbed between the palms of the hands, staining of the palms may be an indication of the presence of clay and silt in fine aggregates. Nevertheless, coarse aggregates should be inspected visually for clay lumps and clay coatings grading and particle shape. Loads containing such lumps should be rejected before discharge [2]. Clay lump are not always obvious and careful inspection of deliveries is advised. Nor, there is no available standard and simple test methods to check the durability and resistance of sand to frost or wear of concrete. Information about the sources of the aggregate is the only mechanism to assess the quality of the aggregate. In general, it will not be necessary to test each aggregate for all the requirements specified in this standard. Consideration of the nature of the aggregate and its sources indicate which characteristics need the periodical examination [7].

To ensure that the proper amount of sand is present, the separate delivery, storage and batching of coarse and fine aggregate is essential. Production of concrete with uniform quality requires a consistent source, grading and moisture content of fine aggregate. Sands coming from beaches are generally unsuitable for good quality concrete, since they are likely to have high concentration of chloride because of the accumulation of salt crystals above the high-tide mark. They are also single-sized, which can make the mix design difficult [2]. In addition, a retaining baffle can prevent segregation of aggregate moving down a sloping surface (Fig. 2.1). The moisture in sand, as batched, should be kept within a practical range of stability. Covered storage is helpful in reducing adjustments through variations in moisture content.

2.3.4 Aggregate Production in Addis Ababa

Recently, construction is booming in Addis Ababa. As a result, there is an increasing demand for construction materials in the city. Aggregates production is one of the major activities that need the attention of the city administration in a bid to meet the demand. Though there were about 152 aggregate production plants in the city, only ten were well organized in man power, in machinery and finance [Addis Ababa Environmental Protection Authority, 2005 cited in 2]. The number of aggregate producers, the total annual production and sales are presented in Table 2.2 and 2.3.

Table 2.2 Number of Licensed Quarries in the city of Addis Ababa (1995–2000)
Construction Material

Sub-city	Basalt	Lgnimbrite	Selected material	Scoria
Bole	80	125	11	–
Nefas Silk	–	100	4	–
Akaki Kality	65	15	–	25
Yeka	6	10	3	–
Kolfe Keranio	1	–	–	–
Total	152	250	18	25

Source: Addis Ababa Environmental Protection Authority, 2005 cited in [2]

Table 2.3 Yearly productions of aggregates and its sales in the city of Addis Ababa (1995–2000)

Budget year	Total Production (M ³)	Total Sales (ETB)
1995/1996	4443798.85	9763574.67
1996/1997	169958.05	11897063.33
1997/1998	384585.10	32689733.50
1998/1999	281385.43	23917761.55
1999/2000	179119.62	15241032.34

Source: Addis Ababa Environmental Protection Authority, 2005 cited in [2]

In the United States, there are about 1200 companies producing crushed stone from 3300 quarries, and 4000 companies produce sand and gravel from 6400 operations. Only five companies account nearly 25% of the aggregate production. Although there are more than 5000

companies are active in the aggregate business, and no single producer dominates the industry. Five of the top ten crushed stone producing companies and three of the ten sand and gravel producing companies are owned by foreigners. Opening new aggregate operations is a complicated process that costs millions of dollars and takes many years. To determine location of potentially aggregate resources, the natural aggregate producers expend tremendous amount of time and money. They also spend huge amount of money and effort in determining the feasibility of production; identifying potential environmental impacts from production; making certain their operation will conform to the relevant laws; and obtaining the necessary permits to extract, process and transport the aggregate [5].

2.4 Handling of Aggregates

Materials handling is not merely a site problem. The designer, the manufacturer and the contractor contribute to its quality. Poor handling of materials increases site costs. Materials waste could be reduced by redirecting under-employed plant and equipment [Johnson, 1981 cited in 2]. Construction materials can be readily available naturally or pass through a manufacturing process. It is usually easy to control the quality of construction materials that pass through a manufacturing process. However, it is very difficult to control the uniformity and quality of construction materials that are available naturally and used directly for construction purposes. This is usually true for concrete making materials especially for the aggregates.

The transportation of sand from the place it is mined up to the place where it can be used takes different modes of transportation. It is the key element in the supply process and takes a large part of delivered price. It can be transported by means of front end loaders, large open topped off road trucks, or dump trucks [11]. In the modern world, aggregates can be transported by rail, water transportation from the source to the place for use. For example, if the sand is once washed, dried, graded and tested, then it can be stored in the form of piles or bagged ready for transporting. The correct weight of sand is packed in a sealed polythene sack, graded and marked with a batch number before transported to end users.

It is very important to take care in handling and stockpiling of aggregates since there is tendency for segregation of the fine and coarse particles to occur. Segregation is the more serious in all

aggregates which contains different sizes. In general, there is less danger of segregation, especially in coarse aggregates when it is split into size fractions and stockpiled separately [3].

Delivery of aggregates contributes to the handling of construction materials. There are different mechanisms of material delivery systems. Materials could be delivered in the form of bulk, bagged, or in pallet form. Construction materials such as hard core, aggregate, pulverized fuel ash, bituminous paving materials, concrete, cement and others are delivered in bulk while small quantities are to be delivered by loose [Johnson, 1981 cited in 2]. The way it is delivered affects the quality of aggregates in general and the distribution and its storage in particular.

The convenient and cheapest method of receiving construction materials is to load and unload them to the place near the production site and to the construction site to be used respectively. This has implications to the handling of different types of aggregates. These materials are often loaded and transported in trucks with elevated sides. The visual inspection of the aggregates when they are delivered contributes to the quality of concrete. In the receiving end, inspection of presence of impurities such as clay, fine silts, fine dust, pieces and soft fragments such as coal and lignite, shale, wood, organic impurities from decay of vegetables, mica in sand, salt contamination and dredged aggregates should be done in order to make the aggregates fit for the appropriate use [8].

Storage has detrimental effect on the quality of aggregates. It should be stored properly so that the uniformity in grading and moisture content will be maintained, and it will be protected from intermingling and contamination by impurities. It is essential to prepare clean, hard base and substantial partitions to separate the different aggregate sizes and to prevent spillage from one bay to another. If clean and hard surface is not prepared for storage, the bottom 300mm of the aggregate stockpile should not be used because of the chance of contamination by dirt and water [Blackledge, 2002 cited in 2]. The moisture content of stockpiles should be kept uniform and this is ensured when the stockpiles are huge. Ideally, the sand stockpiled should stay for 12 hours before use so that the moisture content will be reasonably uniform at about 5–7 %. When sand is very wet the moisture content can be as high as 12–15%. Unless adjustments are made to the water added at the mixer, excessive variations in workability, strength and durability will result.

In large batching plants, the aggregate would probably be lifted by a conveyor system to cover overhead storage hoppers discharging directly into weigh-batchers. The aggregate can be stored in a central area [2]. The concrete production plant shall be positioned so that easy delivery of the parts of the work where the concrete is required. Lorries that deliver aggregates to stockpiles should not preferably follow the same route as the muck shifting plant. Otherwise, they will pick up mud and track into the aggregate bays. The bays for aggregate should be made of concrete floors [10]. When there is lack of proper handling of aggregates at the source of production, in storage places and at construction sites, the problem of segregation, degradation and contamination may happen. Each of this will be discussed below:

Segregation: There should be a special care in the production process of aggregates, because it is the way to produce quality products. This is the time where inputs are properly measured, evaluated, controlled and conformed for the uniformity and suitability of products. It is not always true that jobs are finished when uniform products appear on the last belt. Whenever one rock is placed on the other, segregation can destroy the uniformity of a product. Segregation begins on the belts where the fines vibrate to the bottom and the coarser remains on top. The coarser particles are thrown out and away and the fine particles tend to drop down or, it follows back underneath the conveyor if it is exposed to water [2].

Degradation: The breaking down of the product or degradation takes place when equipment is over running on top of stockpiled aggregates. The degraded portion of the pile is recommended to be discarded before shipping. Degradation may also occur during retrieval where some of the lower portions of the piles are carelessly run over with equipment while loading out. Two years and older stockpiles must be rechecked for gradation before shipping and checking for contents and quality of mineral.

Contamination: Contamination comes from carelessness and poor housekeeping. The stockpiles of different products are dumped or stockpiled in closer place so that they grow together. Equipment can track dirt or other foreign material on stockpiles as it moves over it. The old piles are more subjected to wind-blown fines over time and one should check the cleanness of this before shipping. Figure 2.1 shows the correct and incorrect ways of aggregates handling.

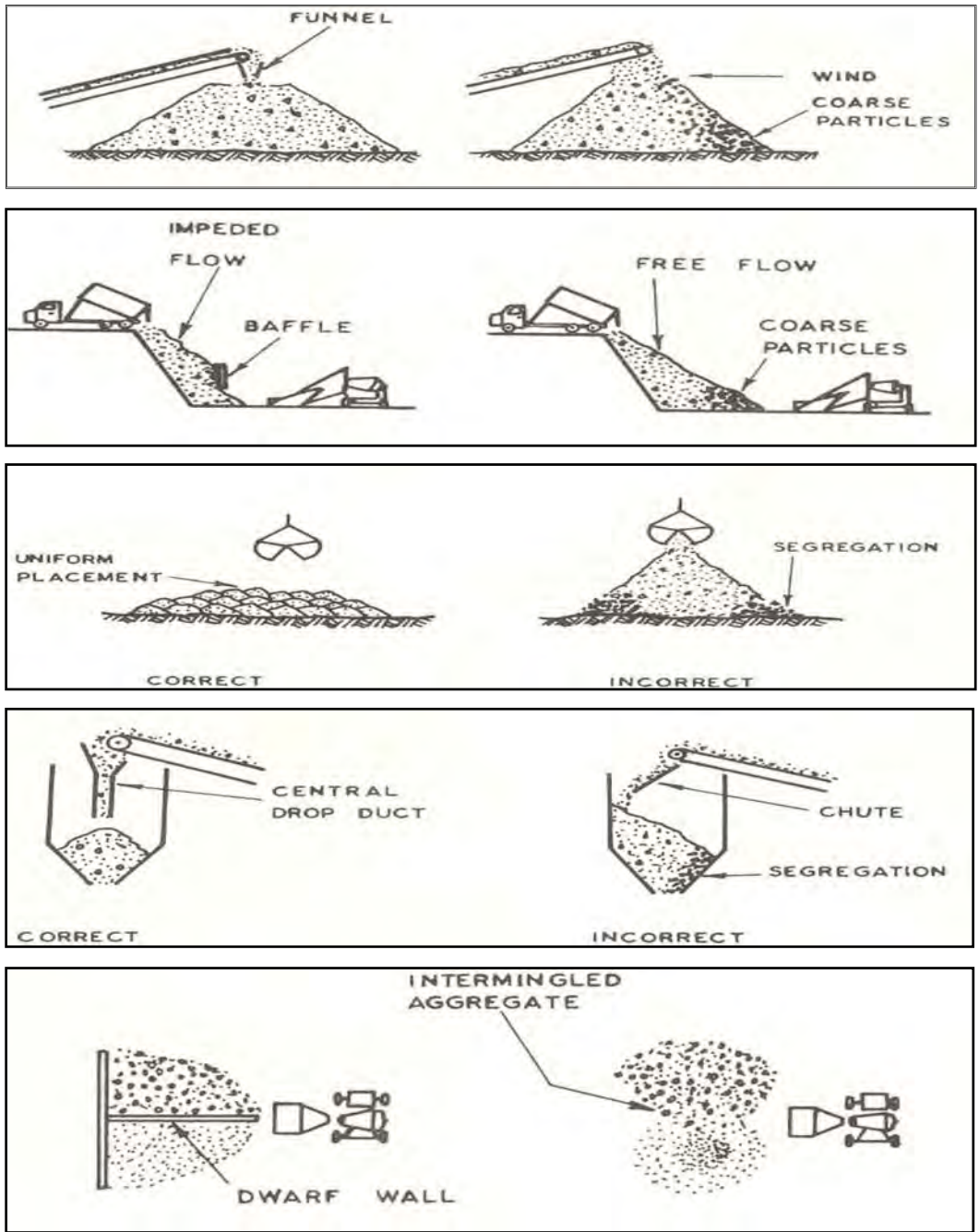


Fig 2.1: Correct aggregates handling methods (Left) and Incorrect aggregates handling methods (Right)

Source: [Mikyias, 1987, cited in 2:46 –47]

2.4.1 Control of Aggregates handling

The control of aggregates handling on the site of construction should begin as soon as the site is handed-over to the Contractor. Aggregates delivered should be compared to the relevant standards in a bid to meet the required quality standards. Wastages and damages of aggregates are common problems when proper supervision is absent. Due attention to aggregate handling is seldom rendered by supervisors and foremen as they leave the responsibility to material suppliers [2]. Site management contributes to appropriate material storage, handling and use. At every stage of operation, appropriate supervision of materials is required (Table 2.4)[2].

Table 2.4: Supervision of materials at different stages of operation

Type of Material	Handling	Storage	Protection	Loss or Waste
Fine & Coarse Aggregates	<ul style="list-style-type: none"> • Delivered by high-sided trucks • Check quality, grade and quantity • Transfer by grab, mechanical shovel or power-assisted equipment on weigh batcher • Transport by bucket, hopper, dumper and barrow. 	<ul style="list-style-type: none"> • In prepared bays adjacent to mixer. • In selected grading and particular size. • On concrete base laid to falls. 	<ul style="list-style-type: none"> • Cover against frost, snow or rain • Avoid contamination • Install steam heating to base of mound • Check calibrations on weighting equipment 	<ul style="list-style-type: none"> • Indiscriminate handling • Contamination of any kind • Failure to trim stocks • Using as site dressing or to fills site voids

Source: [Johnson, 1981 cited in 2:51].

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 [2]. The producer is required to write standard operating procedures on building stockpiles for each product and to educate all those involved in their responsibilities in the procedure. Most stockpiling problems are created because of inconsistent management. The procedures are required to become part of the quality control plan [6].

If truck stock piles from the end of the product belts are thoroughly remixed then truck built stockpiles are capable of greatly minimizing segregation. The best truck-built stockpiles are those that are constructed one dump high with each dump placed against previous dumped material. This procedure, because of the low profile, reduces roll down segregation and allows remixing during load out. However, these stockpiles require more space than others. A technique that may help reduce the required area is to restock some dumps on top of others with a large end loader operating from ground level [6].

Materials are often stored on unprepared ground. Too little thought is given to storage until materials actually arrive on site. Storage areas are then hurriedly selected without thought for the likely hazard. Materials laid directly down on the ground can be affected by moisture and chemical reactions. Topsoil should be removed and set aside elsewhere. The area should be rolled and blended with ashes, and hardcore laid and rolled with slight falls from the center to ensure good surface drainage. When a ground is prepared for storing aggregates in the mixing area a bed of concrete 100mm thick should be laid over the hardcore base and tamped to provide sufficient falls to remove excess water combined with the aggregates either when delivered or due to weather conditions [2].

Construction materials and components are rarely given adequate protections in accordance with the specifications. Usually this is because site personnel do not understand the possible problems that could arise. Physical attack on materials and components can be dealt with easily. Chemical attack is much more a problem. It is very difficult to detect early on, and the only way to avoid it is to take early precaution in storage. Unless aggregates are stored on a properly prepared site, they are likely to be contaminated with mud or clay, which will obviously affect the strength of the concrete mix [2].

Excess supply of materials is more likely to occur on project sites when take-off is performed before final design is completed. Two factors affect the potential materials surplus. One, the timing of the initial orders, and the second is volume of materials purchased. The construction industry has changed considerably in recent years, influencing production rates, construction techniques and the total quantity of materials each year. The increase in the total quantity of

materials used has in turn led to an increase in the amount of waste. Material wastage can be classified as loss through poor site security, inefficient handling, inadequate storage, and misuse in construction or manufacture. If the losses occur at site level, then site control should be improved [2]. Wastage can occur on site for a number of reasons such as misinterpretation of the drawings, an over estimation of the quantities required, the faulty workmanship, careless handling of materials and etc. The preparation and use of materials inevitably creates a certain amount of waste, and this can be assessed in advance. It is true that poor design and poor quality of craftsmen contributes a lot for material wastage in construction [2].

CHAPTER 3: APPROACHES AND DESIGN OF THE PROJECT

3.1 Project Design and Approach

The study has adopted qualitative research approach which fits to the objective of the project that aimed at exploring the handling of aggregates in the construction industry. Qualitative data were collected from both primary and secondary data sources. Exploratory and descriptive research designs were used in the project.

3.2 Area of the Study

The study was conducted in Akaki-Kality and Nefas-Silk Sub-Cities of Addis Ababa where aggregate production plants and many construction sites are available. For the purpose of this study, the researcher selected five aggregate production plants and sand suppliers, two concrete batching plants and four construction sites located in the sub-cities mentioned above.

3.3 Sample Selection, Data Collection and Analysis

Since the study investigated how aggregates are handled in the construction industry, the respondents were purposely selected by the researcher from aggregate production plants, batching plants and construction sites. Interviews were conducted with engineers, foremen, technicians, and staffs of different organizations. They were fourteen respondents and interviewees were selected purposively by looking at their responsibilities. Qualitative data were collected mainly through in-depth interview and observational methods and, in addition to these; some secondary documents were reviewed to find out how aggregates are handled in production, transportation, storing and stockpiling and construction activities. The researcher employed in-depth interview for reasons of flexibility to restructure questions, to collect supplementary information and understand feelings of the respondents more towards the problem under study. The data collected through interviews, observations and document reviews were organized thematically and analyzed qualitatively.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Production of Aggregates

In Addis Ababa, there are many construction projects run by both private owners and the government. As a result, there is huge demand for construction materials. As per the report of the Addis Ababa Environmental Protection Authority [2005, cited in 2], there were 152 aggregate production plants. This has increased to 257 in 2015 (Table 4.1). Since some of the aggregate production sites are recently demarcated within the city's industry district zone, close to 20 producers will cease operation in the near future, which is anticipated to affect the supply of aggregates.

Table 4.1 Number of Licensed Quarries in the city of Addis Ababa

Sub-city	Construction Material					
	Basalt	Lgnimbrite	Selected material	Scoria	Red soil	Hydrafoam
Bole	113	18	30	0	1	0
Nefas Silk	9	11	19	0	0	1
Akaki Kality	117	22	12	19	0	0
Yeka	16	20	13	0	5	2
Kolfe Keranio	2	1	6	3	0	0
Gulele	0	0	0	0	2	0
Total	257	72	80	22	8	3

Source: Own compilation of data collected from Addis Ababa Environmental Protection Authority, 2015

Interview held on 04 October 2015 with an expert working in Addis Ababa Environmental Protection Authority revealed that the Authority is incapable of regulating aggregate producers whether they follow appropriate standards. As mentioned by the expert, most of the visits are paid to new quarry sites until they obtain operating license and supervisions are restricted to quarries with complaints from the dwellers around because of pollution arisen as a result of noise and dust.

The yearly production and sales for the year 1995–2000 was illustrated on table 2.3, but the current average production and sales were not prepared by the experts in the Addis Ababa Environmental Protection Authority. Because of absence of well compiled data, I could not compare it with that of 1995–2000 related to the annual production and sales.

4.2 Practices of Handling of Aggregates

4.2.1 Practices of Handling of Fine Aggregate in the Supply Site

The supply of sand is from different sources and is transported by dump trucks from outside Addis Ababa. Some of the sources mentioned by the suppliers were from Lafesa, Meki, Agura, Tuti, Suti, Alemtena, Langano and Mojo. Since the source of fine aggregates has implications to the handling of aggregates, I decided to look into the way fine aggregates are handled. The sources were natural from Rivers and sandy area mountains. In Hana Mariam area, I observed two of the stock piled supply of sand (Fig. 1.4a and 1.4b). In these sites, sand from different sources were mixed up and prepared for sale by the laborers. During time of supply, the suppliers include light-weight material deposited nearby Alemtena and Meki area and the sand from this area is transported by dump truck in such a way that the heaped volume of about 1000mm high from the level of the dump truck will be showered by water in order to increase the volume and make it a close resemblance to river sand. The suppliers call this practice in Amharic *Mefedem* and the sand is called in Amharic as *Tejietu*. The cost of buying this mixed sand is 30% less than the cost of river sand. The place where they were preparing and sold was dusty and the quality was not as per the standards. For example, I took a handful of sand and rubbed between palms of my hands, stain of silt was observed in the palms. This indicates that the sand consists of an excessive amount of clay and silt which does not fit for construction unless washed. Nevertheless, people still use this type of sand for its low cost and insufficient knowledge about the results of using such type poor construction materials on the quality of concrete and other related works.



Figure 4.1a: Mixing sand from different sources at Hana Mariam site

Source: Own picture, 2015



Figure 4.1b: Mixing sand from different sources at Hana Mariam site

Source: Own picture, 2015

The other sources of sand observed on construction sites were from rivers. Some of the supplies were not pure and my field test result revealed that 8%, 23.5% silt content was found in the sample taken from stockpiles of the case studies. A similar laboratory test conducted by Saba Engineering for Anbesa Shoe Share Company for its expansion and relocation of the factory in Akaki-Kality Sub-city showed that the silt and clay content was 5%, 12.44% [15]. The sand with silt and clay content more than 6% had been washed before use as per the instruction of the consultants. The third source of sand was the crushed sand from aggregate production plants that will be discussed in 4.1.2. Since it was a rainy season, sand suppliers were unable to bring pure sand for construction projects from rivers (Fig. 4.2, 4.3); and the use of the crushed sand was allowed based on the test results taken from the site.



Figure 4.2: River sand supplied on the construction site

Source: Own picture, 2015



Figure 4.3: Supply of fine aggregate at Kality,
Source: Own picture, 2015

4.2.2 Practice of Handling of Coarse Aggregates in the Production Site

Five aggregate production plants were selected, (Fig.4.4a, b, c, d, e).some of these were established 30–40years ago (Fig. 4.4a, 4.4e). In all crushing plants it was observed that aggregates were produced and placed on the ground that is not asphalt or concrete finished. In almost all plants there was too much dust at the base of all products aggregates contrary to the literature. Although different products were produced in the crushers, they were placed adjacent to each other without any demarcation so that there would not be uniformity in some mixed products. The products were taken by loaders from the crusher to the appropriate place of stock pile.

The gradation on the production was observed in the crushing plants that we could not find a well-graded aggregate product in the appropriate place. But these products were sold for the clients and used as it is without any further blending. In addition to this the interview respondents replied that because of the bulkiness of the materials it is difficult to place in a well finished ground and place a demarcation among different sizes. The producers sell for products without checking the appropriate gradation and other requirements. No more tests were conducted in these crushers in order to check its gradation, because of the scarcity of the products, the users purchase without further investigation of the requirements.

The Ministry of Urban Development and Construction has no sufficient documents related to aggregate production in an organized manner. One of the officers responded that the ministry had no full documents related to the construction materials in Addis Ababa and they know that there exists the gap in the production of aggregates and the ministry planned to have the construction department to regulate and fulfill the necessary gaps in the production and supply of construction materials in the construction industry.



Figure 4.4a: Aggregate Production Plant

Source: Own picture, 2015



4.4b Aggregate production plant

Source: Own picture, 2015



Figure 4.4c: Aggregate Production Plant

Source: Own picture, 2015



Figure 4.4d Aggregate Production Plant

Source: Own picture, 2015



4.4e: Aggregate Production plant

Source: Own picture, 2015

Segregation: As stated on the literature, segregation starts at the production stage. This phenomenon was observed in all crushing plants. Segregation was visualized as a result of vibration of the machine; segregation was seen on the sieves and conveyor belts. The provision of funnel, baffle, central drop ducts, dwarf walls etc were not observed in all crushers.

Gradation: Degradation or breakdown of the product is often caused by equipment running on top of the aggregate when it is being stockpiled. When this occurs the degraded portion of the pile must be discarded before shipping. Degradation may also occur during retrieval where some of the lower portion of the pile is carelessly run over with equipment while loading out. Piles two years and older should be rechecked for gradation before shipping and possibly even for mineral quality. This phenomenon was observed on crushing plants, aggregate production plants and construction sites in such a way that the loaders overrun on the top of products in order to load the aggregate on dump trucks that ultimately affects the gradation of the aggregates and it was observed that the degraded portions were loaded on dump trucks for use.

4.2.3 Practices of Handling of Aggregate in a Batching Plant

The literature states that Aggregates should be stored so that they are kept as uniform as possible in grading and moisture content, and protected from intermingling and contamination by other foreign materials. If clean, hard base is not provided, the bottom 300 mm of each aggregate pile should not be used, since dirt and water can accumulate there. It is essential to provide substantial partitions to separate the different aggregate sizes and to prevent spillage from one bay to another. As the engineers responded, the batching plants have their own course aggregate manufacturing plants and the other has suppliers. These products were inspected and checked in the quarry and will be transported to the batching plant, where as the fine aggregate is a river sand purchased from suppliers and its quality is checked by taking gradation and silt content tests. This batching plant has clean hard base made of reinforced concrete and side concrete shear walls which separates different sizes of aggregates and prevents the aggregates from entrance of foreign harmful substances that will cause serious damages in the future permanent structures. Though the bottom and sides are well prevented, the top part is exposed to the atmosphere and dust.

The literature stated that stockpiles should be as large as possible, as this helps to ensure uniformity of moisture content. Ideally, stockpiled sand should be allowed to stand for 12 hours before use so that, apart from the lower part of the stockpile, the moisture content will be reasonably uniform at about 5 –7 %. When sand is very wet the moisture content can be as high as 12–15%. Unless adjustments are made to the water added at the mixer, excessive variations in workability, strength and durability will result. A large stockpile of sand was observed in this plant, the moisture content is more or less similar, but this section is not well protected as that of coarse aggregate. It is simply protected by corrugated iron sheet fence that will not safe guard as that of the concrete shear walls and was not top covered and exposed to dust, and grasses were grown on stockpiles figure 4.5.



Figure 4.5a: Handling of Aggregates in Concrete Batching Plant

Source: Own picture, 2015

In the second batching plant (fig.4.5b), the aggregates were not stockpiled and stored on well prepared ground and an appropriate demarcation between different sizes of aggregates was not provided. The fine aggregate was placed adjacent to the coarse aggregate that the two different sizes were mixed each other; this inappropriate mixture will result in producing poor class of concrete. Therefore, handling of aggregates was not as per the recommendation in the literature.



Figure 4.5b: Handling of Aggregates in Concrete Batching Plant

Source: Own picture, 2015

4.2.4 Practices of Storing and Stockpiling of Aggregates in Construction Sites

Four construction sites were selected for the investigation of aggregate handling figure 4.6, a, b, c, d. The literature states that Aggregates should be stored so that they are kept as uniform as possible in grading and moisture content, and protected from intermingling and contamination by other materials. If clean, hard base is not provided, the bottom 300 mm of each aggregate pile should not be used, since dirt and water can accumulate there. It is essential to provide substantial partitions to separate the different aggregate sizes and to prevent spillage from one bay to another. But in the actual construction sites situations were observed that all fine and coarse aggregates were dumped or placed on unprepared ground near by the construction sites. They place the aggregates whichever is suitable or accessible to the concrete mixing place. Not only this but also cement bags, grasses, mud and other foreign materials were mixed with the aggregates and when supervisors are not checking, the aggregate are used up to the bottom which jeopardize the quality of the construction.

A comparative quantitative analysis was made to show the costs and benefits of stockpiling of aggregates with and without constructing hard concrete base in Akaki-Kality Sub city as a show-case. First, area measurement was taken where the aggregates were stockpiled. Sand was stockpiled in an area of 547m² and coarse aggregate was stockpiled in an area of 720.50m². It is assumed that the bottom 300mm of the stockpile will not be used since it will be mixed with dirties. With this measurement, the total volume of aggregates wasted will be:

Wastage of sand in volume=547*.30=164.10m³

Wastage of coarse aggregate in volume=720.50*.30=216.15m³

Multiplying the volume of aggregates wasted with the market value of sand and coarse aggregates will give us the following amount:

Sand: 164.10m³ *470ETB/m³ = ETB 77,127.00

Coarse aggregate: 216.15m³ *466 ETB/m³ = ETB100, 725.90

Therefore, the total cost of wasted aggregate will be ETB 177,852.90

Alternatively, if a concrete hard base for stockpiling is constructed for storing aggregates, the cost structure is estimated. The estimation is done for preparing a concrete hard base for 1m², and the rate was later used to arrive at the total cost of constructing storage. The details are presented in the following table.

Table: Cost structure of constructing a concrete hard base for stockpiling of aggregates

SN	Description	Unit	Quantity	Rate (ETB)	Amount (ETB)
1	Clear top soil to an average depth of 200mm	M ²	1	16	16
2	Fill selected material to an average depth of 400mm under hard core	M ³	0.40	250	100
3	Cart away the excavated top soil to a distance not exceeding 5km	M ³	0.20	60	12
4	250mm thick basaltic or equivalent stone hard core	M ²	1	130	130
5	C-15 concrete for 100mms thick ground slab	M ²	1	230	230
Total					488.00

Source: Own estimation based on Contractor's rate operating at Akaki-Kality Sub-city

From the table, the cost of preparing a concrete hard base for stockpiling is ETB 488 /m². As per the project engineer of the site, stockpiling 105m³ of fine aggregate and 210m³ of coarse aggregate estimated to be enough as a reserve in the site. Further, I make the following assumption about the dimensions of the concrete hard base to stockpile aggregates in the site:

For coarse aggregate: A stockpile 3.5mts high, tent shaped with a base width of 8mts (radius of ends=4mts) and a length of 12mts for central section, then the volume of the stockpile would be:

Given: D=8mts, H=3.5mts, L=12mts, R=4mts

$$\text{Volume} = (1/2 * D * H * L) + (2 * .5 * 3.14 * R^2 * H / 3)$$

$$\text{Volume} = (1/2 * 8 * 3.5 * 12) + (2 * .5 * 3.14 * 4^2 * 3.5 / 3) = 226.60 \text{m}^3$$

For fine aggregate: A stockpile 3.5mts high, tent shaped with a base width of 6mts (radius of ends=3mts) and a length of 7mts for central section, then the volume of the stockpile would be:

Given: D=6mts, H=3.5mts, L=7mts, R=3mts

$$\text{Volume} = (1/2 * D * H * L) + (2 * .5 * 3.14 * R^2 * H / 3)$$

$$\text{Volume} = (1/2 * 6 * 3.5 * 7) + (2 * .5 * 3.14 * 3^2 * 3.5 / 3) = 106.47 \text{m}^3$$

Using the above dimensions and volumes, let the area of the stockpile for aggregates be as follows:

- The area for stockpiling of the coarse aggregate = 12mts*16mts =192m²
- The areas for stockpiling of the fine aggregate = 10mts*11mts =110m²
- Total areas for stockpiling of aggregates= 302m²

Cost for making a hard concrete base for 302m² will be given as:

$$302 \text{m}^2 * 488 \text{ETB} / \text{m}^2 = \text{ETB } 147,376$$

Therefore, for this specific site preparing a hard concrete base storage place costs the project much less than the value of wasted aggregates stockpiled in unprepared storage place. Proportionally, the value of the wastage is 26.6% higher than the cost of constructing a hard concrete base storage area. This is a conservative estimate and if the project operators shift to

other unprepared storage location by abandoning earlier ones, the cost of the wastage will be much higher than this estimate.

In the construction sites, there is no also proper demarcation between fine and coarse aggregates so that the adjacent fine and coarse aggregates were mixed without the right mix proportion that will be used later without any care figure 4.6a–d. The respondents from the construction sites said that most of the time aggregates are placed in places near by the concrete mixing areas regardless of the preparation for the ground and the bottom end will be used for lean concrete, but not in the real case. Some of the engineers said that it is a tough task to do such a job that construction is a complicated in its implementation, workers and machine operators does not perform as per the instruction.

The literature stated that stockpiles should be as large as possible, as this helps to ensure uniformity of moisture content. Ideally, stockpiled sand should be allowed to stand for 12 hours before use so that, apart from the lower part of the stockpile, the moisture content will be reasonably uniform at about 5–7 %. When sand is very wet the moisture content can be as high as 12–15%. Unless adjustments are made to the water added at the mixer, excessive variations in workability, strength and durability will result. In the real practice of construction the concept of moisture content is not well recognized by the contractors as well as other regulatory bodies. Sometimes the aggregates are used as soon as delivered on site without maintaining uniform moisture content.



Figure 4.6a: Handling of Aggregates in Construction Site

Source: Own picture, 2015



Figure 4.6b: Handling of Aggregates in Construction Site

Source: Own picture, 2015



Figure 4.6c: Handling of Aggregates in Construction Site

Source: Own picture, 2015



Figure 4.6d: Handling of Aggregates in Construction Site

Source: Own picture, 2015

4.3. Challenges of Handling of Aggregates

The practices of handling of aggregates are made worse due to various challenges that the sector is facing to date. From the interview results, it was inferred that there is weak supervision and follow-up by responsible regulatory bodies in terms of checking the quality standards of aggregates in the production, supply and construction sites as well as in the concrete batching plants. The Addis Ababa Environmental Protection Authority (AAEPA) is under-staffed to regulate quarry and aggregate producers and suppliers. In addition, the majority of the aggregate production and supply sites are located in poor infrastructure sites and thus, supervision by regulatory bodies cannot be done easily.

Lack of awareness from the side of suppliers and buyers about the likely consequences of poor handling of aggregates in the quality of building construction is another challenge that worsened the problem of aggregate handling. This calls for the need to create awareness and perhaps provide training on the issue, more importantly to the suppliers of the aggregates.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusions and recommendations of the study are included.

The whole study of this paper is based on answering the following questions:

1. What are the practices of aggregates handling in construction industries in Addis Ababa?
2. To what extent do the concerned government regulatory bodies engaged in the control of proper handling of aggregates?
3. What measures should be taken to have proper aggregates handling in the construction industry?

5.1 Conclusions

- In all aggregate production plants, the ground for storing and stockpiling are not well prepared and protected from dust and other foreign substances.
- Careful handling of aggregates, strong clean hard base and proper demarcation between different sizes of aggregates are absent in the aggregate production plants.
- The production plants are not regularly inspected by the consultants of different projects, clients, contractors and concerned governmental agencies.
- The source of fine aggregate were from river and sand deposit areas that most of the suppliers do not take care of quality and proper handling during supply.
- Most of the aggregate production plants are located in the lower land areas. As a result, the products are exposed to contamination caused by floods.
- Degradation or breakdown of the products was observed on the aggregate production, construction sites and batching plants as result of machines running over the stockpiles of aggregates.
- A good concrete finished ground slab and side shear walls in order to separate different sizes of aggregates and safe guard the aggregates from entrance of foreign substances was properly prepared only in one of the batching plants. But the top of the aggregates were not covered that dust particles and foreign materials may affect the quality of the product. But the fine aggregate has no side protecting partition and top covers. But in the second batching plant, aggregates were not handled as per the recommendation in the literature

- Fine and coarse aggregates are placed adjacent to each other, so that there is a tendency of mixing of fine with coarse aggregates, and may be used without appropriate proportioning.
- Segregation and degradation were observed in production quarries, batching plants and construction sites that will affect the quality of concrete.

5.2 Recommendations

On the bases of the findings derived and conclusions drawn with regard to handling of aggregates in the construction industry. The following recommendations are made with the hope that implementation would reduce the problems identified.

- The contractors should give especial attention on handling of aggregates by introducing the proper cares on handling and giving awareness to the site engineers, foremen and workers.
- The consultants should inspect the proper aggregate handling on the aggregate production plant, batching plants and construction sites and should create awareness in the contractors that are always involved in the construction industry.
- The consultants should establish and include well detailed document on handling of construction materials issues that would be part of contract document when they prepare contracts of construction projects.
- The main duty of the Ministry of Works and Urban Development is preparing and issuing policies and directives in respect of construction activities, conducting studies and prepares code of practices, standards around all the disciplines etc, should give especial focus on handling of construction materials. Standardization of aggregates should be put in place by concerned regulatory bodies.
- The site should be organized in such a way that proper allocation of materials in a clean well finished grounds so that no deterioration of materials will occur.

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Annexes

Interview Guides for Owner and Foreman in Aggregate Quarry

1. When was the firm established?
2. What is the overall procedure of aggregate production?
3. How much you care for handling of aggregates?
4. Do the regulatory bodies control the firm? If yes, how often?
5. What do you suggest for the future in relation to aggregate handling?

Interview Guides for Engineer and Foreman in Construction Sites

1. How do you place or stockpile the aggregates in the site?
2. Do you take care on handling of aggregates?
3. Do the supervisors or any regulatory bodies give due attention for handling of aggregates while inspecting the sites?
4. What do you think of aggregate handling on construction sites to be for the future?

Interview Guides for Engineer and/ Foreman in Concrete Batching Plants

1. How is the overall process of concrete production in your batching plant?
2. How do you stockpile the aggregates in batching plant?
3. Do you take care on handling of aggregates?
4. Is there any regulatory body in related to aggregate handling in your batching plant?
5. What do you suggest for future related to aggregate handling for better flow of inputs and achieving better output?

Interview Guides for Sand Suppliers

1. What are the main sources of sand you supply?
2. How much you care to bring the sand that fits for construction?
3. How much you care for handling of sand during transporting from the source up to the construction sites/ any supply point?
4. What do you think of handling of aggregates in the future?

Interview Guides for Experts in Addis Ababa Environmental Protection Authority

1. What is the role of Addis Ababa Environmental Protection Authority?
2. What do you observe in aggregate production quarries related to aggregate handling?
3. What are the number of aggregate producers, their annual production and sales?
4. Do you regulate the aggregate production quarries regularly?
5. What do you suggest about future production of aggregates in relation to the available natural resources?

Interview Guides for Experts in Ministry of Urban Development and Construction

1. What is the role of Ministry of Urban Development and Construction in relation to aggregate production/ supply in the construction industry?
2. Do you control the aggregate production quarries regularly? If yes how often?
3. What do you suggest about handling of aggregates in the construction industry?
4. Are there documents that show the annual consumption of construction materials in the industry?

Interview Guides for Experts in Addis Ababa Housing Project Office

1. Who are the suppliers of aggregates? And the number of suppliers?
2. What is the annual consumption of aggregates for your projects?
3. Is there shortage of aggregates?
4. How is the aggregate handled in the production and supply?
5. What do you suggest for better future supply of aggregates?

Check lists for observations (by the researcher) on construction sites

1. Stockpiles of aggregates

- a) Is it placed on concrete ground slab? Yes no
- b) Is segregation observed? Yes no
- c) Is there contamination? Yes no
- d) Is there demarcation between products? Yes no
- e) Is stockpiling well planned? Yes no

2. The source of sand

- From river Yes no
- From crushed sand source Yes no
- Is its quality checked before used Yes no

3. How do you check the quality of aggregates? Simple visualization tests

Check lists for observations (by the researcher) on concrete batching plants

1. Stockpiles of aggregates

- e) Is it placed on concrete ground slab? Yes no
- f) Is segregation observed? Yes no
- g) Is there contamination? Yes no
- h) Is there demarcation between aggregates? Yes no
- f) Is stockpiling well planned? Yes no

2. The source of sand

- From river Yes no
- From crushed sand source Yes no
- Is its quality checked before used Yes no

3. How do you check the quality of aggregates? Simple visualization tests