ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

HANDLING OF CONCRETE MAKING MATERIALS IN THE ETHIOPIAN CONSTRUCTION INDUSTRY

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

By

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October 2005

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DEDICATION

To my beloved family: My father Ato Addissie Nuramo, my mother Woizero Aster Gitchamo, my elder brother Dr. Adamu, my younger sister Helen and my two younger brothers Yishak and Thomas. Thank you for all your support.

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LIST OF ABBREVATIONS

A.A.	Addis Ababa
ACI	American Concrete Institute
AD	Air Dry
ASTM	American Society for Testing and Materials
BS	British Standard
DIN	Deutsche Industrie Norm
ES	Ethiopian Standard
OPC	Ordinary Portland Cement
PPC	Portland Pozzolana Cement
Fig.	Figure
F.M.	Fineness Modulus
ft.	feet
gm	gram
hr	hour
IS	Indian Standard
in.	inch
Kg	Kilo Gram
KN	Kilo Newton
lb	Pound
lt	liter
m	meter
mg	milligram
ml	milliliter
mm	millimeter
Max.	Maximum
MPa	Mega Pascal
NO.	Number
SSD	Saturated Surface Dry
t	ton
U.K.	United Kingdom
U.S.	United States
Wt.	Weight

ABSTRACT

Construction materials management is an important element in the management of construction projects. One of the construction materials widely used in construction projects is concrete. Concrete being one of the important constituents of many of the construction projects, in addition to its subjectivity to variability, requires a close and thorough care and handling in construction projects. The constituents of concrete, which majority of them occur naturally, are subjected to a wide range of variability and quality problems. Therefore, with this respect a research was carried out to assess the situation of handling of concrete making materials in the Ethiopian construction industry with a special emphasis given to the concrete making aggregates. The objective of the research was to assess the current situation of the handling of concrete making materials in the Ethiopian construction industry in general and to give recommendation inline with the outcome of the results of the research. There fore, in the research test results of fine aggregate, coarse aggregate and rock samples were collected and analyzed. According to the result, 44%of the coarse aggregate samples considered and 77% of the fine aggregate samples considered couldn't satisfy requirements set by different standards. In addition, it has been found out that more than about 60% of the tests that the samples failed to satisfy don't attribute to the natural quality of the materials. Further, researches carried out in different parts of Ethiopia had also shown that the naturally available material have quite acceptable quality to be used as a concrete making material. The research also indicates that the reason why concrete making materials fail to comply with requirements attributes to the handling of the materials in the construction industry but not to the unavailability of materials satisfying requirements in Ethiopia. Further, from the observations made in construction sites and aggregate production plants in addition to the interviews made with relevant personnel, it was concluded in the research that the aggregate production in Ethiopia is not up to the standard with respect to quality, quantity and production process. Another conclusion drawn from the research was that the aggregate production process and handling of concrete making materials in the Ethiopian construction industry should be upgraded in all aspects including expert training, utilization of improved production process and introduction of standardization both for the quality of the materials and the production processes. Finally, from observations made in Germany the study concluded that introduction of a ready-mixed concrete production system to the Ethiopian construction industry could improve the current situation with respect to better handling and production of good quality concrete.

Key words: concrete, fine aggregate, coarse aggregate, cement, handling, quality, production

1. INTRODUCTION

1.1 GENERAL

The construction activity accounts for 6-9% of the Gross Domestic Product (GDP) of many countries. In addition, the total annual value of construction works in the world ranges from 1-1.5 trillion dollars. It is also believed that construction accelerates the economic growth of a nation. However, there is a vast scope for improving performance through knowledge in the construction industry, where men, materials, machinery, money and management work together to build a facility [1].

It is a known fact that, resource planning and management is one of the most important parameters for competitiveness and profitability in today's construction technology. One important aspect of resources management is management of construction materials in construction projects [2].

Good project management in construction must vigorously pursue the efficient utilization of labor, material and equipment. Improvement of labor productivity should be a major and continual concern of those who are responsible for cost control of constructed facilities. Material handling, which includes procurement, inventory, shop fabrication and field servicing, requires special attention for cost reduction with acceptable standard quality [1].

1.2 CONSTRUCTION MATERIALS MANAGEMENT IN CONSTRUCTION PROJECTS

Materials management is defined as the management system for planning and controlling all the necessary efforts to ensure that the right quality and quantity of materials and installed equipments are appropriately specified in a timely manner, and obtained at a reasonable cost, and are available when needed. Especially, management of construction materials is generally recognized to be the integrated coordination of materials takeoff, purchasing, expediting, receiving, ware housing, proper utilization and disposal. When these functions are not properly managed, materials shortages, surpluses, and cash flow problems are likely to occur. Costly labor delays result when the required quantity and quality of construction materials are not available when needed [3].

Materials management is an important element in project planning and control. In construction projects, materials account for more than 40% of the project cost. A small saving in materials cost, say even 5%, through efficient management of materials, can result in a large contribution specially, when competitive bidding is for small profit margins, varying from 3.5% to 10% of the project cost [1]. A research carried out in Ethiopia had shown that construction materials constitute 57% of the total budget allocated for construction works [4].

Broadly, the term 'materials' denotes all purchased items utilized at the project site including construction materials, supporting plant and equipment, and administrative facilities and stores. Construction materials cover all types of materials used in construction including electrical and mechanical fittings, fixtures, devices and instruments that are incorporated during the construction of permanent works and temporary supporting works at site [1].

The materials for delivery to and from a construction site may be broadly classified as: (1) bulk materials, (2) standard off-the-shelf materials, and (3) fabricated members or units. Bulk materials refer to materials in their natural or semi-processed state, such as earthwork to be excavated, wet concrete mix, gravel, sand etc. that are usually encountered in large quantities in construction. Standard piping and valves are typical examples of standard off-the-shelf materials. Fabricated members such as steel beams and columns for buildings are pre-processed in a shop to simplify the field erection procedures [1].

1.3 IMPORTANCE OF CONSTRUCTION MATERIALS MANAGEMENT SYSTEMS IN CONSTRUCTION PROJECTS

Two formal researches were conducted by a task force established by the American Construction Industry Institute jointly with Auburn University and Texas AM University. The findings of the research conducted in the real world construction project execution, established several basic premises [3]. The findings of the researches are summarized as follows.

1. Materials management is a clearly defined task that, when properly planned and executed, provides project management with an invaluable tool to optimize schedules and improve labor productivity.
2. Substantial savings have accrued to both the owner and the contractor. An estimate of 6% savings on the projects craft labor costs appeared conservative for most applications.
3. As with any management system, it requires top management support.
4. Training is an essential element in the successful application of the materials management concept.

A research carried out in Nigeria to find out the causes of high construction costs in the country has depicted shortage of construction materials as the first and most important cause. In this same research, the following points were put as reasons of materials shortage in the construction industry [5]:

1. absence of adequate statistics on the material availability;
2. fluctuation in the availability of some construction materials;
3. very long average waiting time and uncertainty in the delivery of ordered materials; and
4. Shortage of funds to procure materials and inadequacy of transportation.

1.4 FUNCTIONS OF CONSTRUCTION MATERIALS MANAGEMENT SYSTEMS IN CONSTRUCTION PROJECTS

Efficient construction materials management in project environment calls for an integrated approach covering numerous functions such as materials planning and programming, materials purchasing, inventory control, store-keeping and ware housing, materials transportation and handling at site, materials codification and standardization, and the disposal of surpluses.

One important aspect in materials management is expedition. The purpose of expediting is to provide timely information regarding anticipated materials deliveries to all concerned project personnel. When material is received, it is inspected and formal material-receiving report is completed. Once goods are purchased, they represent an *inventory* used during the construction process. The general objective of inventory control is to minimize the total cost of keeping the inventory while making tradeoffs among the major categories of costs.

1.5 Benefits of Effective Construction Materials Management Systems

- **Improved Craft Labor Productivity**

The benefits associated with improved labor productivity on projects that use integrated materials management systems are believed to be due to two interrelated factors: Materials are more likely available when needed, and craft supervision can plan the work around material availability [6].

- **Reduced Bulk Materials Surplus**

A surplus of materials is more likely to occur on projects in which the take off function is being performed before final design drawings are available. Two factors affect the potential materials surplus: the timing of the initial orders, and the volume or percentage of materials actually purchased in the early buys [6].

- **Reduced Materials Management Manpower**

When an effective materials management system is placed in place, experienced materials professionals will be assigned to perform the field control and warehousing functions that are traditionally performed by craft personnel. The fact that these tasks are performed by persons trained specifically in the materials discipline tends to reduce field manpower requirements [6].

1.6 HANDLING OF CONCRETE MAKING MATERIALS

Construction materials can be readily available naturally or pass through a manufacturing process to be used directly for construction purposes. 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.

Concrete is one of the oldest construction materials in the construction industry and it is widely used through out the world. It is suitable to almost all types of constructions starting from foundations, road pavements, dams, buildings of various types etc. However, the process involved in the production of concrete requires due care and attention. The care starts from the selection and estimation of the amounts of constituents of the concrete. The materials used for concrete production should satisfy certain requirements in order to get the concrete of the desired strength and durability with a reasonable economy.

Concrete is produced from different construction raw materials that can be both manufactured and naturally available. Cement is one of the constituents of concrete and is a result of a factory manufacturing process. The rest constituents that are aggregates and water are naturally available and are usually used directly for construction purposes. Hence, due consideration should be given in selecting and using theses materials for concrete production. The purpose of careful handling and control, in proper sequence, of these concrete making materials is to produce satisfactorily a selected batch assembly for the continuous production of homogeneous concrete.

In keeping the quality of concrete in line with acceptable standards, one should concentrate in the properties of the concrete making materials. In the Ethiopian construction industry there is always a problem of producing concrete which satisfies standard requirements. It is a normal practice in and around Addis Ababa to see concrete produced using 400kg of cement per cubic meter of concrete failing to achieve a C-25 grade [13]. One reason for this is the failure of concrete producers to use proper concrete making materials for the concrete production.

Research carried in Addis Ababa has shown that over 50% increase in compressive strength can be obtained simply by using aggregates that have different physical properties, but having similar grading limit and silt content. The different aggregate types (fine and coarse) do not have appreciable cost differences but the magnitude of strength variation resulted is highly significant. Thus, the result depicts the economic advantage in concrete production by saving cement, which is the most expensive construction material in concrete production by selecting better quality aggregate, grading and keeping the silt content within the allowable limit [14].

In the same research , with the addition of superplasticizer, it was possible to produce concrete with a mean compressive strength of 91 MPa (C80) using the available concrete making materials in the country [14]. This shows how the construction industry benefits from an effective and efficient handling of concrete making materials.

It is a known fact that, construction materials management in construction projects in Ethiopia is done usually by experience and using traditional methods. It is also viable that lack of proper construction materials management system in the country contributes to the high construction cost and poor quality of construction products in Ethiopia. Researches have indicated that lack of proper materials management is one of the causes of claims in Ethiopia. Therefore, the mentioned issues signify the need to develop an effective constructions materials management system in construction projects in Ethiopia in general and handling of concrete making materials in the construction industry in particular with an ultimate result of a completed project with good quality and within the schedule.

1.7 OBJECTIVES

General Objective

Assessment of the current situation of handling of concrete making materials in the Ethiopian construction industry in general and formulate and give recommendations with respect to handling of concrete making materials in accordance with the outcome of the research.

Specific Objectives

1. Assessment of the supply of concrete making aggregates with respect to consistency, uniformity and quality.
2. Assessment of the supply and demand situation of concrete making materials in the Ethiopian construction industry.
3. Assessment of the quality and availability of natural sources of concrete making materials in Ethiopia.
4. Analysis of the effect of aggregate failing to meet the requirement, on the quality of the resulting concrete and its ultimate financial consequences on Contractors or concrete producers.
5. Comparing the situation of handling of concrete making materials in Ethiopia with one developed country, Germany.

1.8 METHODS

Sources and Collection of Data

1. Literature survey
2. Survey at selected active (under construction) projects and construction materials production plants in and around Addis Ababa and in Germany. The survey includes observation, on site data collection and conducting interviews.
3. Collecting results of different tests done on concrete making materials that are collected from different parts of Ethiopia.
4. Collecting relevant data from governmental institutions and large construction materials suppliers and producers in Ethiopia and in Germany.
5. Use of internet web sites to find relevant information

Processing of Data

1. Simple statistical analysis of test results.
2. Comparing the practice of the Ethiopian construction industry with the German construction industry with respect to handling of concrete making materials.

Conclusion

Formulation of recommendation from the results obtained.

1.9 APPLICATION OF RESULTS

The results will be applicable to the Ethiopian construction industry towards an effective construction management system in general and handling of concrete making materials in particular.

Possible Beneficiaries of the Results

- Contractors
- Consultants
- Project owners
- The general public
- Educational Institutions
- Professional Associations (Ethiopian Civil Engineers Association, Ethiopian Contractors Association, Architects Association)
- Future studies in construction management and related topics

2. HANDLING OF CONCRETE MAKING MATERIALS IN CONSTRUCTION PROJECTS

2.1 GENERAL

It is generally accepted that the initial selection of materials plays major part in achieving a satisfactory construction product. Unfortunately, it is not always so easily recognized that the methods adopted on site for handling and storing these materials are equally important. In addition, the production method followed by material producers and the means of selecting material sources is not usually given the attention it requires. Further, manufacturers and suppliers might go to great lengths to provide products that comply with recognized standards, but much of their effort can be eroded if the same importance is not attached to the product when it is transferred to the care of the construction team [7].

2.2 HANDLING OF CONCRETE MAKING MATERIALS

2.2.1 GENERAL

Concrete is a composite material that consists essentially of binding medium with in which are embedded particles or fragments of a relatively inert mineral filler [8]. In some cases, admixtures may be added to give the concrete special properties [9]. The usual concrete in use in Ethiopia and throughout the world is Portland cement concrete. In Portland cement concrete the binder or matrix, either in the plastic or in the hardened state, is a combination of Portland cement and water. The filler material, called "aggregate," is generally graded in size from a fine sand to pebbles or fragments of stone which, in some concretes, may be several inches in diameter [8].

When these materials are mixed and placed in forms and allowed to cure, the chemical reaction between the water and cement forms a hardened binding medium or cement paste which surrounds and holds the aggregates together[9].

There are three different ways of producing concrete :

1. On site mixing – concrete ingredients batched and mixed on site
2. Ready-mixed concrete – concrete is delivered for placing from a central plant
3. Precast concrete – both mixing and placing is done in a central plant

For practical concrete mixes, the cement, water and aggregates should be so proportioned that the resulting concrete has the following properties [9]:

A. When freshly mixed it is *workable* enough for economical and easy uniform placement, but not excessively fluid,
B. When hardened it posses *strength* and *durability* adequate to the purpose for which it is intended.
C. It involves minimum *cost* consistent with acceptable quality.

2.3 WATER

The function of the water, other than enabling the chemical reactions that cause setting and hardening to proceed, is to lubricate the mixture of aggregates and cement in order to facilitate placing. Some standards stipulate that water fit for drinking is generally suitable for making concrete [9]. Water quality is the most consistent of the constituents of concrete but water quantity, as it affects the free/water cement ratio, is most important for control of consistence, strength and durability.

Water used for concrete mixtures should contain no substance which can have an appreciably harmful effect on strength or upon durability of the concrete in service [8]. Substances in water which, if present in large amounts, may be harmful are: salt, oil, industrial wastes, alkalis, sulphates, organic matter, silt, sewage etc. Tests by the sense of smell, sight or taste would reveal such impurities; however water of doubtful quality should be submitted for laboratory analysis and tests [9]. Water should be avoided if it contains large quantities of suspended solids, excessive amounts of dissolved solids, or appreciable amounts of organic materials [10]. In addition, the amount of water used should be the minimum necessary to ensure thorough compaction of the concrete [11]. Since this research is maily focused on concrete making aggregates, the discussion made concerning water is not detailed.

2.3.1 TESTING OF WATER FOR CONCRETE PRODUCTION

There are no specifications and standard tests for water quality in the ASTM. However, BS 3148 specifies two methods of assessing the suitability of water for concrete making. These involve comparing both the setting time and the compressive strengths of specimens made with the appropriate cement and both the water in question and distilled water. The water is considered to be suitable if it neither changes the setting time by more than 30 min, nor reduces the strength by more than 20% compared to the specimen made with distilled water.

Other specifications often used in United States require that the 7 & 28 day strengths should be at least 90% of those obtained on comparable specimens made with potable water. If there is doubt as to the suitability of a particular water sources, an alternative supply should be sought [10].

2.4 CEMENT

Nowadays, after several important technical improvements, concrete made with Portland Cement is probably the most used manmade material in the world. In a concrete mixture the function of the cement is to react with the water forming a plastic mass when the concrete is fresh and a solid mass when the concrete is hard. Since the most widely used cement is Portland cement, the discussion made in this paper is primarily on this cement type only. Portland cement is a finely powdered substance, usually gray or brownish grey, composed largely of artificial crystalline minerals, the most important of which are calcium and aluminum silicates [8].

Portland cement, by definition (ES. C. D5. 201. 1990), is a cementing material that is obtained by

> *thoroughly mixing together calcareous or other lime bearing materials with, if required, argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resulting clinker.*

In addition, the Ethiopian Standard (ES. C. D5. 201. 1990) states that Portland cement shall contain no additions after burning except as provided below:

- *Water or calcium sulphate, or both, may be added in optimum amounts such that the requirements for chemical composition shall not be exceeded.*
- *Processing additions such as grinding aid may be used in the manufacture of the cement, provided that such materials shall not be harmful in the amounts used and shall comply with the requirements 5.1*[1]*.*
- *Traces, of metallic substances which may result from grinding process shall not be regarded as additions.*

[1] Quality requirements which include chemical composition.

2.4.1 CEMENT PRODUCTION IN ETHIOPIA

Ethiopia had four cement production plants with a combined production capacity of nearly 1.52 million metric tons per year (Mt/yr) of cement and 1.36 Mt/yr of clinker in 2003. Currently there are still four cement factories in the country with a total production capacity of more than 1.67 million metric tons per year.

According to forecasts by the International Cement Review (2003), national cement consumption was predicted to rise to 1.1 million t in 2003 from 1 million t in 2002 and 900,000 t in 2001. Though, the produced amount was higher than it is predicted to reach in 2003, a shortage in cement was experienced in Ethiopia in that year. This shows that the consumption of cement in Ethiopia was above that predicted to reach in 2003 by the International Cement Review. Higher consumption of cement was attributable to the construction of new roads and hydroelectric dams. Currently, Mugher Cement Enterprise is planning to build two new cement factories at Dire Dawa in eastern Ethiopia and Mugher near Addis Ababa at a cost of about $350 million .

The cement production trend in Ethiopia is shown in Table 2.1. As the trend shows there is an increase in production and selling price of cement in Ethiopia in all the years from 1996 to 2002. In addition, when the production and consumption of cement in Ethiopia is considered, statistical figures show that it is far below even some underdeveloped countries in the world as shown in Table 2.2 and Fig 2.1.

Table 2.1 Cement production trend in Ethiopia from 1996 to 2003 [35].

Year	Quantity Produced (Tons)	Avg. Producers Price (Birr)
1996/97	774669	473.18
1997/98	469548	549.04
1998/99	815632	527.96
1999/00	919169	527.82
2000/01	819047	582.62
2001/02	-	-
2002/03	890181	826.83

Germany has been experiencing a recession in the construction industry for the last ten years. During that period total construction investment has declined by about 20%. Although limited during that period there was a downturn of 2.6% of cement production in 2004.

One of the important indices that indicate the activity of the construction industry is cement consumption of countries [12]. Accordingly, though the German construction industry is not as active as it was before, it has a comparatively good cement consumption index, which is 347. This has to be seen in line with the fact that Germany has already a strong infrastructure facility.

It is believed that infrastructure is a key aspect towards the economic development of countries. Further, it is a known fact that it is impossible to think of infrastructure development with out the development of the construction industry. In addition, cement consumption index can be used as an indicator of the development of the construction industry of countries. However, the situation in Ethiopia is quite different. As shown in Table 2.2 and Figure 2.1 the cement consumption index of Germany is 23 times that of Ethiopia. Further, the cement consumption index of Ethiopia is even lower than a number of developing African countries. This indicates that the construction industry in Ethiopia is not as active as it should be.

Table 2.2 A Comparative Cement Consumption in different countries [12].

Country	Yearly Production[2] (Million Tonnes)	Consumption per capita[3] (Kg/person)
Luxembourg	0.55	1227
Spain	48.01	1087
Portugal	09.11	1041
Italy	45.77	709
Austria	4.62	570
Switzerland	4.19	554
China	704.72[4]	548
Germany	28.84	347
France	20.00	339
United States	91.27	318
Egypt	23.00	315
U.K.	13.05	205
South Africa	8.53	194
India	100.00	96
Kenya	1.23	39
Ethiopia	1.67	15
Eritrea	0.045	11
Sudan	0.19	5

[2] 2004
[3] 2002
[4] Source: **U.S. Geological Survey and U.S. Census Bureau**

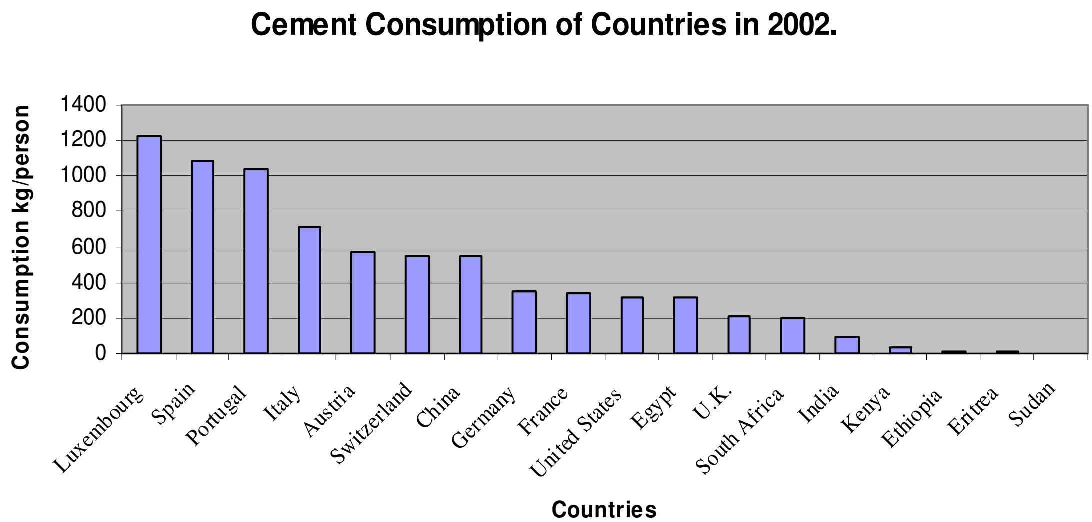


Fig 2.1 Cement consumption per capita of different countries in the world [12].

2.4.2 TYPES OF PORTLAND CEMENTS

There is wide variety of cements that are used in the construction and building industries, or to solve special engineering problems. The chemical compositions of these cements can be quite diverse, but by far the greatest amount of concrete used today is made with Portland Cements. The main types of cements can be classified as shown in Table 2.3 below [9].

Table 2.3 Main Types of Portland cement and their Uses [9].

European Description	A.S.T.M.	Use
Ordinary Portland	Type I	For general concrete construction where special properties are not required.
Modified Cement	Type II	For general concrete construction exposed to moderate sulphate action or where it is required that the heat of hydration be somewhat lower than for normal cement.
Rapid Hardening Portland	Type III	For use when rapid hardening is required.
Low Heat Portland	Type IV	For use where it is required that the heat of hydration be a practicable minimum.
Sulphate Resisting Portland	Type V	For use where a high resistance to the action of sulphate is required.
Portland Pozzolana	Type IP	For use especially in mass construction because of low rate of heat development resulting from low hydration.
White Portland	-	For use in architectural concrete or where a pastel colour paint finish is required such as in tropical countries. It is also used in making highway lane, stainless mortar, stucco & building blocks
Portland Blast Furnace	Type IS	-

The name Portland originates as a trade name and thus applies to a family of closely related cements that have an overall similarity of properties. Different Portland cements can be made for particular applications by multiplying certain properties [10]. So far the types of cements produced in Ethiopia are Ordinary Portland, Portland Pozzolana and white cement respectively.

2.4.3 TESTS ON THE PROPERTIES OF PORTLAND CEMENT

Standards such as ES.C.D5.201.90 and ES.C.D8.490.90 specify requirements for the composition and manufacture of Portland cement, methods of sampling, testing for chemical composition and physical requirements. The standards are specified: 1) in recognition of the fact that Portland cement is industrially manufactured from naturally occurring raw materials and hence its mineral composition could vary depending on the proportions of the raw materials, their mineral compositions, and the methods applied in the manufacturing process, and 2) in order to detect inferior products that deviate from the standards [9].

2.4.3.1 Chemical Tests

Chemical tests are normally conducted by the manufacturer on regular basis in order to check the quality of the product. They may also be conducted in research laboratories in order to determine the compound composition of cement used in a particular research. However, they have little importance to the ordinary consumer [9]. The Ethiopian Standard, ES. C. D6. 201 1990, sets quality requirements of Portland cement as follows:

- **Lime Saturation Factor (L. S. F.)**

The lime saturation factor shall not be less than 0.66 or more than 1.02 when calculated by the following formula:

$$L.S.F = \frac{CaO - 0.7(S0_3)}{2.8(SiO_2) + 1.2(Al_2O_3) + 0.65(Fe_2O_3)} \tag{2.1}$$

- **Alumina-iron Oxide Ratio (Al_2O_3 : Fe_2O_3)**

The ratio of the percentage of alumina (aluminum oxide) to the percentage of iron oxide shall not be less than 0.66.

- **Magnesia (MgO)**

The mass of magnesia (MgO) contained in Portland cement shall not exceed 5.0 percent.

- **Sulphur trioxide (SO_3)**

The mass of sulphur trioxide contained in Portland cement shall not exceed 3 percent if the tricalcium aluminate (C_3A) is 8 percent or less, and shall not exceed 3.5 percent if the tricalcium aluminate exceeds 8 percent.

- **Loss in Mass on Ignition**

The total loss in mass when Portland cement is heated to a temperature of 925 ± 25^0c shall not exceed 4 percent.

- **Insoluble Residue**

The mass of insoluble residue shall not exceed 1.5 percent.

2.4.3.2 Physical Tests

In addition to chemical composition, ES. C. D5. 201 1990 requires that Portland cement conforms to the relevant physical requirements for fineness, setting time, soundness and strength.

- **Fineness**

According to the standard, Portland cement when tested for fineness must have a specific surface of not less than 2250 cm^2/g when ordinary and not less than 3250 cm^2/g when rapid-hardening.

- **Setting Time**

The minimum initial setting time specified by the standard is 45 minutes.

- **Soundness**

Portland cement when tested for soundness must not have an expansion of more than 10mm. If the cement fails to comply with this requirement, an additional test, to comply with this requirement, is called for using aerated portion of the same sample. The maximum expansion of such an aerated sub-sample must not exceed 5mm.

2.4.4 TYPICAL PROPERTIES OF PORTLAND CEMENTS PRODUCED IN ETHIOPIA

Chemical compositions and physical properties of different cements produced in Ethiopia is shown in Table 2.4 and Table 2.5 respectively. The compositions given in the tables signify the fact that cements produced in Ethiopia satisfy quality requirements of the Ethiopian Standard.

Table 2.4 Chemical Compositions of Cements Produced in Ethiopia [13,14]

No	Oxide composition	Percentage			ES. D5. 201/202	
		Messobo OPC	Mugher OPC	Mugher PPC	For OPC	For PPC
1	Calcium oxide	64.15	61.60	46.21	-	-
2	Silicate oxide	21.23	20.59	34.21	-	-
3	Aluminum trioxide	5.24	5.34	6.71	-	-
4	Ferric oxide	3.87	3.6	4.12	-	-
5	Magnesium oxide	1.72	0.87	0.71	Max.5.0%	Max.5.0%

Table 2.5 Physical Properties of Cements Produced in Ethiopia [13, 14]

No	Specification	Messobo OPC	Mugher OPC	Mugher PPC	ES. D5. 201/202 For OPC	ES. D5. 201/202 For PPC
1	Fineness [cm^2/g]	3,000	-	4480	Min. 2250	Min. 2600
2	Chemical composition (%)					
	Lime saturation factor	0.94			Min. 0.66 Max. 1.02	
	Insoluble residue	0.50	0.35	24.48	Max 1.5	-
	Magnesia	1.49				
	Loss on ignition	0.96	2.36	2.95	Max 4.0	Max 4.0
	Sulphuric anhydride (SO_3)	2.50	2.4	2.59	Max 3.5	Max 3.0
3	Compressive strength (MPa) (average of 3 mortar cubes):					
	3 days	33.50		13.6[5]		Min. 10
	7 days	46.02		23.6		Min. 16
	28 days	56.97		38.5		Min. 25
4	Setting time (min.)					
	Initial	187		174	Min. 45	Min. 45
	Final	298		234		Max.10hrs.
5	Soundness (mm)	1.86		1.0	10	10

2.5 AGGREGATES

In a concrete mixture the aggregates which are generally graded in size from fine to pebbles or crushed stones, form the inert mineral filler material which the cement paste binds together. These aggregates generally occupy 65 to 75 percent of the volume of concrete. In choosing aggregate for use in a particular concrete attention should be given, among other things, to three important requirements [9]:

[5] This is value of the compressive strength at the 2nd day.

- **Workability** when fresh for which the size and gradation of the aggregate should be such that undue labor in mixing and placing will not be required.
- **Strength and durability** when hardened- for which the aggregate should
  1) be stronger than the required concrete strength
  2) not contain impurities which adversely affect strength and durability of the concrete
  3) not go into undesirable reaction with the components of cement
  4) be resistant to weathering action
- **Economy of the mixture**- meaning to say that the aggregate should be
  1) available from local and easily accessible deposit or quarry
  2) well graded in order to minimize paste, hence cement requirement

Cement is the most expensive of the materials used to make concrete. For this reason and because the aggregates provide a relatively cheap filler, it is advisable to use as much aggregates as a given amount of paste will bind together. In addition to being a relatively cheap filler, the aggregates reduce the volume changes resulting from the setting and hardening process and from moisture change in the paste [9].

In order to provide a dense packing, or arrangement of particles in place, in a concrete mass, the aggregate must be suitably graded from fine to coarse. In general, the more aggregate that can be crowded into a given volume of concrete, the more economical is the resulting product. On the other hand, with the given amount of aggregate per unit volume of concrete, the more workable a mix is as the result of suitable gradation - the lower the water requirement and the greater the strength [8].

2.5.1 FUNCTIONS OF THE AGGREGATES

The aggregates have three principal functions: (1) to provide a relatively cheap filler for the cementing material; (2) to provide a mass of particles which are suitable for resisting the action of applied loads, abrasion, the percolation of moisture, and the action of weather; and (3) to reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste [9].

The properties of concretes resulting from the use of particular aggregates depends upon (1) the mineral character of the aggregate particles, particularly as related to strength, elasticity, and durability; (2) the surface characteristics of the particles, particularly as related to the workability, density, and economy of the mix; and (3) the amount of aggregate in unit volume of concrete, particularly as related to cost and to volume changes due to drying [8].

Aggregate particles that have an angular shape or a rough texture, such as crushed stone, give greater strength for a given free water/cement ratio but need more water than smooth and rounded particles to produce concrete of the same consistence. With smaller sized aggregates, the amount of sand needed to fill the voids increases in water demand. To maintain the free water/cement ratio necessary for strength and durability, at the specified consistence, more cement and /or admixture is necessary [11].

The sand and coarse aggregates need to be proportioned to produce a stable and cohesive mix at the required consistence with the minimum amount of water. Badly proportioned constituents require an excessive amount of water to achieve the required slump and this will result in concrete of lower strength and durability, as well as resulting in a mix prone to segregation [11].

2.5.2 PROPERTIES OF AGGREGATES

To know more about the concrete it is very essential that one should know more about the aggregates that constitute major volume in concrete. Cement is the only factory made standard component in concrete. Other ingredients, namely, water and aggregates are natural materials and can vary to any extent in many of their properties [12].

The physical properties like specific gravity, porosity, thermal, and the chemical properties of an aggregate are attributed to the parent rock. However, the shape and surface texture of natural aggregates and the density, porosity, in addition to shape and surface texture in artificial aggregates are attributed from the mode of production. It is, therefore, very important to give a due consideration to the source and mode of production of aggregates.

2.5.3 CLASSIFICATION OF AGGREGATES

Aggregates are generally classified based on either their source, their chemical composition, their weight, their size or the mode of preparation. However, the method of classification widely used in concrete works is based on aggregate size. Aggregates bigger than 4.75 mm in diameter are classified as coarse aggregates and those smaller than 4.75 mm are classified as fine aggregates. In some countries all-in aggregate, an aggregate composed of both fine and coarse aggregate is made available in the market [9].

2.5.3.1 MINERALOGY AND PETROGRAPHY

Rocks are naturally occurring crystalline, cemented or consolidated materials that form the immediate crust. They are subdivided into types according to mineralogical, petrological and physical characteristics [15]. Almost all natural aggregate materials originate from bed rocks. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic [12].

a. Aggregates from Igneous Rocks

Most igneous rocks make highly satisfactory concrete aggregates because they are normally hard, tough and dense. Therefore, bulk of the concrete aggregates, that are derived, are of igneous origin [12].

The most widespread of all the igneous rocks are basalts. Basalts are dark colored, fine-grained extrusive rocks. The mineral grains are so fine that they are impossible to distinguish with the naked eye or even a magnifying glass. Most basalts are volcanic in origin and were formed by the rapid cooling and hardening of the lava flows. Some basalts are intrusive having cooled inside the Earth’s interior.

b. Aggregates from Sedimentary Rocks

The quality of aggregates derived from sedimentary rocks will vary in quality depending upon the cementing material and the pressure under which these are originally compressed. Some siliceous sand stones have proved to be good concrete aggregate. Similarly, the limestone also can yield good concrete aggregate [12].

The thickness of the stratification of sedimentary rock may vary from a fraction of a centimeter to many centimeters. If the stratification thickness of the parent rock is less it is likely to show up even in an individual aggregate and there by it may impair the strength of the aggregate. Such rocks may also yield flaky aggregates. The degree of consolidation, the type of cementation, the thickness of layers and contamination, are all important factors in determining the suitability of sedimentary rock for concrete aggregates [12].

c. Aggregates from Metamorphic Rocks

Many metamorphic rocks particularly quartzite and gneiss have been used for production of good concrete aggregates [12].

Classification of rocks according to their mode of formation is summarized in Table 2.6.

Table 2.6 Classification of Rocks According to their Mode of Formation

Igneous	Sedimentary	Metamorphic
Formed from the solidification of molten rock 1. Volcanic - Basalt - Trachyte 2. Plutonic - Granite	Formed as strata as a result of sedimentation from the disintegration products derived from rocks. - Sand stone - Lime stone - Shale	Either igneous or sedimentary that has been altered structurally and mineralogically by heat or pressure or both acting together.
They are very good concrete making materials.	If hard, sand stone and lime are good materials for concrete.	They are of minor interest for building purposes except marble.

It was found in some literature that the type of rock normally used for concrete production in Ethiopia is igneous rock. Especially, basalt and rhyolites are widely used. In addition to igneous rocks, sedimentary rocks such as black lime stones are also used for concrete production [22].

2.5.3.2 CHEMICAL COMPOSITION

There are three main classes of aggregates differing in their chemical composition and these are derived from argillaceous, siliceous or calcareous rocks as it is shown in Table 2.7[9].

Table 2.7 Classification of rocks according to their chemical composition

Argillaceous	Siliceous	Calcareous
Composed primarily of aluminum (Al_2O_3) the chief component of clay	Composed primarily of silicon dioxide (SiO_2), the principal ingredient of quartz sand	Composed primarily of calcium carbonate or lime ($CaCO_3$)

2.5.3.3 WEIGHT

Based on their weight, aggregates are divided into three groups: 1) heavy aggregates with specific gravity more than four, 2) normal weight aggregates with specific gravity between 2.4 and 3.0 and 3) light weight aggregates such as pumice and scoria which are used to make light weight concrete [16].

Lightweight aggregates

All light weight materials are relatively weak because of their high porosity, which gives them reduced weight. This imposes a limitation on strength. Lightweight aggregates are used to reduce weight in structural elements or to give improved thermal insulation [11].

Mikyas (1970) investigated the concrete making properties of lightweight aggregate using concrete made with Ethiopian pumice and scoria. Satisfactory structural capacity was obtained in addition to reduction of imposed dead loads on structures [24]. Use of local lightweight and cheaper Ethiopian aggregate (scoria) as a replacement to crushed rocks had been studied by Girma(1982). The structural properties of lightweight aggregates, which were used with varying proportions to normal weight, were found to be structurally sound [25].

Pumice

Pumice is a very light, porous igneous rock that is formed during volcanic eruptions. It is made up of very tiny crystals, since they cool so quickly above ground. The texture of pumice is rough and has many hollows and cavities. In fact, it forms from frothy lava that has lots of gas bubbles trapped in it, and all those little holes used to have gas trapped in them. It has bulk density of 500 to 900 kg/m^3. The varieties of pumice, which are not too weak structurally, make a satisfactory concrete with a density of 700 to 1400 kg/m^3 and with good insulating characteristics, but high absorption and high shrinkage.

Scoria

Scoria rocks are igneous rocks that are found when lava cooled quickly above ground. One can see where little pockets of air had been. Scoria is actually a kind of glass and not a mixture of minerals. It is abundantly found in Addis Ababa and along the rift valley, on occasions newly formed scoria is observed along sides of the road to Metahara.

2.5.3.4 SOURCE

As regards the source, aggregates may be natural or artificial. Natural aggregates are obtained from river beds (sand, gravel) or from quarries (crushed rock) while artificial aggregates are generally obtained from industrial wastes such as the blast furnace slag [9]. Classes of aggregates with respect to their source is shown in Table 2.8. Almost all aggregates used for construction is natural in origin. In addition to natural gravels and crushed rock, a number of manufactured aggregates are available for use in concrete [11].

Table 2.8 Aggregate Classification With Respect to their Source

Natural	Artificial
Sand, Gravel, Crushed Rock such as Granite, Quartzite, Basalt, Sandstone	Broken Brick, Air cooled slag

In most parts of Ethiopia sand is obtained from river beds while coarse aggregate is prepared from crushed rock and sold as crushed stone aggregate. In south western regions of Ethiopia (Illubabor, Kaffa, Gamu-Gofa) where river sand is scarce, fine aggregate is prepared from stone as crushed sand. Crushed stone aggregate, course or fine, can also be prepared at the construction site from lumps supplied with trucks [9]. However, no artificial aggregate is produced in Ethiopia. Except the sources of scoria, the majority of aggregate sources in Addis Ababa are located around rivers within the city. The big river banks of Akaki River and Matahara River (around Bole Airport) are the main sources for the production of coarse aggregate in Addis Ababa.

In Germany natural sand and gravel are collected from river beds; however, crushed rock aggregate is usually used for high strength and special concrete production. In addition, crushed rock is also used as fine aggregate where natural sand is not available. Since the crushed aggregates have sharp granular surface they produce concrete of better strength than smooth surfaced gravel. This is important for the proper utilization of aggregate sources. In addition, artificial aggregate is also used for concrete production in Germany.

The mode of production of the aggregates differs depending on the type of aggregate produced. The two dominantly produced aggregates, lightweight namely scoria and normal weight basalt do have different modes of production. The light weight aggregate is produced from quarries by simple digging or bulldozing as it is a soft material and the different sizes produced mainly depend on digging or bulldozing. The normal weight aggregates, on the other hand,are drilled, blasted or dug with special mechanisms, fed to crushers, sieved and separated according to their sizes. In Ethiopia, the different sizes commonly known as Fine, 01, 02, 03 and 04 are produced and stockpiled separately. In Germany, the types of aggregates normally produced are 0-4mm, 2-8mm, 8-16mm and 16-32mm to be used as fine aggregate and 2-5mm, 5-8mm, 8-11mm, 11-22mm and some times 8 – 16 mm to be used as coarse aggregate.

2.5.3.5 PARTICLE SHAPE AND TEXTURE

Further, aggregates may be classified on visual inspection in terms of particle shape and texture (BS 812), as is shown in Table 2.9.

Table 2.9 Shape and Texture of Aggregates [15]

Characteristic	Classification	Description	Examples
Particle shape	Angular	Well-defined edges at the intersection of rough faces, and three dimensions nearly equal.	Crushed rocks of all types; rubble; crushed slag.
	Elongated	Particles, usually angular, having a length/width ratio greater than 3.	-
	Flat or flaky	Particles having a width/thickness ratio greater than 3.	-
	Flat and elongated	Particles having width/thickness and length/width ratios greater than 3.	Crushed or laminated rock.
	Irregular	Naturally irregular or partly shaped by attrition, having rounded edges and three dimensions nearly equal.	Pit gravel, land or dug flint.
	Misshapen	Either flat or elongated, or flat and elongated particle.	Crushed or laminated rock.
	Rounded	Fully water-worm or shaped by attrition, and three dimensions nearly equal.	River or seashore gravel; desert, seashore and wind-blown sand.
Surface texture	Crystalline	Easily visible crystalline constituents.	Granite, gabbro, gneiss
	Glassy	Concoidal fracture.	Black flint, vitreous slag.
	Granular	Fracture showing more or less uniform rounded grains.	Sandstone
	Honey-combed and porous	Visible pores and cavities.	Pumice, scoria, clinker, foamed slag, expanded shale or clay, brick.
	Rough	Rough fracture of fine-grained or medium-grained rock with no easily visible crystalline constituents.	Basalt, felsite, porphyry, carboniferous limestone.
	Smooth	Water-worn or smooth due to fracture of laminated or fine-grained rock.	

2.5.4 RESEARCHES ON LOCAL AGGREGATES IN ETHIOPIA

A research was carried out to test the potential use of local normal weight aggregates for the production of high strength concrete. The result confirmed that the locally available basalt stone can reasonably be used to produce concrete of higher strength. With the application of super plasticizers, concrete strength of 90MPa was obtained. This result was obtained by proper selection of aggregates (removing friable particles), limiting the maximum size of aggregates (higher strength can be attained with smaller maximum sizes), washing (to remove material finer than No. 200 sieve) and using higher quantity of cement in combination with limiting the w/c ratio. Nevertheless, from this result it is possible to see that the widely used concrete class C-25 is a low grade as compared to the potential of producing higher strength concrete[26].

A research conducted around Mekele (Tigrai) indicated that the existing raw materials in the area are suitable for construction purposes. According to the research, the better crushed aggregate source in the area is black limestone. The soundness and Los Angeles Abrasion varies from 17.9 to 21 % and 2.9 to 4.7% respectively [41]. Table 2.10 summarizes the Los Angeles Abrasion and soundness loss values of different aggregates in the study area [41].

Table 2.10 Test results of rock samples taken from quarry sites around Mekele

No	Type	Los-Angeles Abrasion (%)	Soundness Loss (%)	Location
1	Crushed Aggregate	17.9	2.9	Quiha (Limestone)
2	Crushed Aggregate	19.6	4.7	Quiha (Limestone)
3	Crushed Aggregate	21	3.7	Adulis quarry site (black limestone)
4	Sand	-	1.9	Gereb-giba (20 km from Mekele)
5	Natural Aggregate	24.1	10.4	Quarry (5 km from Business College)

According to the result of the research, the best rock that can be used to produce good quarry site for aggregate in the area is the black finely crystalline limestone. The other rock units were either weak, difficult to shape or crush them. A sulphate content of up to 0.44% was found in some rocks of the study area, indicating its damaging effect to concretes or other infrastructures upon contact with water. This indicates the need for special protections for structures placed in such materials [38].

In addition, a report of a research carries out in Awassa indicated that from engineering point of view, the rocks outcropping in the town area were grouped in to two: strong (basalts and rhyolites) and weak rocks (dominantly of basaltic hayalloclastites). From field Schmidt hammer test result, it was found out that the former ones have an unconfined strength in the range from 310 to greater than 700 kg/cm^2, while the latter less than 100 kg/cm^2. The strong ones were found out to be good sources for aggregates while the weaker ones are not suitable for most of civil engineering works. The results of the chemical analysis and physical tests of the rocks are summerized in Table 2.11 and Table 2.12 respectively[39]. Therefore, the above mentioned researchs give an indication that good quality aggregate for concrete production is available in both places of Ethiopia.

Table 2.11 Chemical Analysis data for rocks of the study area [42]

Sample Type	Location	Sio_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	TiO_2	P_2O_5	H_2O	LOI
Basalt	Tumura	47.92	15.87	12.32	8.89	5.46	1.68	0.12	0.21	4.02	0.59	0.27	0.21
Rhyolite	Kika	75.82	9.94	4.32	0.14	0.13	3.55	4.31	0.13	0.21	0.06	0.68	<0.01

Table 2.12 Aggregate test result for the rhyolite sample from kika ridge [42]

Test Type	Test Result	Maximum Allowable	Procedure
Soundness Test by sodium sulphate			ASTM C33
(% loss)	0.86	12	
Abrasion (% wear)	10.18	50	ASTM C33
Stripping (%)	Above 95%	Above 95%	ASTM D1669
Flakiness Index (%)	23	35	BS 882
Bulk Specific Gravity	2.42		
Bulk Specific Gravity (SSD)	2.43		
Apparent Specific Gravity	2.46		
Water Absorption (%)	0.67		

2.5.5 AGGREGATE TYPE SELECTION

As aggregates form the bulk of the volume of concrete and can affect its performance, the selection of a suitable material is important [11]. Many properties of aggregates depend mostly on the quality of parent rock. However, there are some properties possessed by the aggregates which are important so far as concrete production is concerned. These properties have no relation with the parent rock, particularly the shape and size . In addition, selection of aggregates is required to be done judiciously taking the economic factor into consideration.

The aggregate that can be delivered to the mixing plant directly may not be the most economical one. It may require a cement content more than that of another source. Also very often, the cost of some processing accomplishes the reduction in cement content of the concrete. In general, the aggregate that brings about the desired quality in the concrete with least over all expense, should be selected [12].

2.5.6 DETERMINATION OF AGGREGATE REQUIREMENT

For the calculation of batch quantities, for making mix adjustments, for computing effective water - cement ratios and yields, and for making estimates of quantities required for jobs, some of or all of the information like specific gravity of aggregate particles, unit weight of aggregate in bulk, free moisture and absorption and gradation of aggregate are needed [8].

Methods that have been used or are used to choose the relative proportions of the various sizes are as follows [8]:

1. Trial mix of the concrete to obtain maximum economy with good workability
2. Empirical criteria based upon
   a. Unit weight or void content
   b. Sieve analysis and grading diagrams
3. Trial mixtures of dry aggregates to obtain maximum density
4. Rule- of - thumb ratios

The first method is probably the most satisfactory in the long run, since the final criterion of optimum proportions is a concrete which most nearly possesses the necessary economy and workability. However, with more than two sizes of aggregate the number of trials may become large, so that familiarity with the significance of unit weights and gradations (method 2) serves as an excellent guide to the most desirable combinations. The third method may also serve as a guide, except that, as has been pointed out, maximum density of dry aggregates doesn't give optimum workability in a concrete mixture, so that either trial mixes or empirical modification of proportions is still necessary [8]. However, there is no standard procedure in Ethiopia for concrete mix design. Due to this reason concrete producers in Ethiopia are obliged to use mix design procedures developed for other countries.

2.5.7 PROPERTIES OF CONCRETE MAKING AGGREGATES

As much as the aggregate occupies 65 to 75 percent of the volume of concrete the importance of having information on the physical and chemical characteristics can not be over emphasized.

2.5.7.1 Specific Gravity

The specific gravity of a substance is the ratio of the unit weight of the substance to the unit weight of water. Applied to aggregates, the term specific gravity customarily refers to the density of the individual particles, not to the aggregated mass as a whole [8].

In connection with concrete mix calculations, it is desired to know the spaces occupied by the aggregate particles with in the relatively thick cement paste regardless of whether or not pores or internal voids exist within the particles. Hence, there is determined what is called *the bulk specific gravity* of the particles. The bulk specific gravity is defined as the ratio of the weight in air of a given volume of a material at the standard temperature to the weight in air of equal volume of distilled water at the standard temperature. For use in the computation of concrete mixes the bulk specific gravity is always determined for saturated surface dry aggregates. The specific gravities of a number of commonly used aggregates fall with in the range of 2.6 to 2.7, although there are satisfactory materials for which the specific gravity falls outside this range [8].

2.5.7.2 Unit Weights and Voids

Unit weight is the weight of a unit volume of aggregate, usually stated in kg per cubic meter. In estimating quantities of materials, and in mix computations when batching is done on a volumetric basis, it is necessary to know the conditions under which the aggregate volume is to be measured: (1) loose or compact, and (2) dry, damp, or inundated [8]. The general range in unit weights of some fine and coarse aggregates are shown in Table 2.13.

Table 2.13 General Range in Unit Weight of Some Natural Aggregates

Material	Kg/m^3
Sand (dry)	1520 – 1680
Gravel	1280 – 1440
Crushed Stone	1250 – 1400

Bulk density measures the weight of the aggregate that fills a container of unit volume part of which is void because of loose packing of the particles. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. In general, for comparison of different aggregates and calculation of mix quantities the standard conditions are dry and compact (rodded). However, for scheduling volumetric batch quantities, the unit weight in the loose, damp state should also be known [12].

2.5.7.3 Surface Moisture, Porosity and Absorption

As regards moisture content, the various states in which an aggregate may exist are: (1) Oven dry (2) Air dry (3) Saturated surface dry and (4) Damp, or wet [8]. In proportioning the materials for concrete, it is always taken for granted that the aggregates are saturated and surface dry [12].

It should be noted that if the aggregates are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the water/cement ratio. Both these conditions are harmful for the quality of concrete. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the water/cement ratio is kept as exactly as per the design [12]. Therefore, in calculating or measuring quantities for concrete mix it is important to know the state at which the aggregate is used [9].

Absorption represents the total water contained in the aggregate in the saturated surface-dry condition and the surface moisture (or free moisture) is the water in excess at the saturated surface-dry state. The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. The surface or free moisture content is generally given in terms of percent of the weight of the saturated surface dry aggregates [9].The absorption capacity is a measure of the porosity of an aggregate. Approximate values of the absorption capacities of some types of aggregates are given in Table 2.14.

Table 2.14 Approximate absorption capacities of some types of stones used for aggregate

Material	Absorption capacity % by wt.
Sand	0 – 2.0
Gravel	0.5 – 1.0
Basalt	0 – 0.5
Granite	0 – 0.5
Limestone (firm)	0.5 – 1.0
Sand stone	2 – 7.0
Trap rock	0 – 0.5

Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete. The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids [12].

The porosity of aggregate is important since it affects its bulk specific gravity, permeability and absorption which in turn affect the properties of the resulting concrete. Unless their openings are very wide, the surface pores are considered impermeable to cement paste because of its viscosity. Hence, the gross volume of the aggregates particle, including the surface pores of narrow opening, is considered to be solid for the purpose of calculating the aggregate content in concrete [9].

Determination of moisture content in aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability and strength. The measurement of the moisture content of aggregate in the field must be quick, reasonably accurate and must require only simple apparatus which can easily be handled and used in the field. Some of the methods that are being used for determination of moisture content of aggregate are: (i) Drying method (ii) Displacement method (iii) Calcium Carbide method and (iv) Measurement by electrical meter [12].

Bulking of Fine Aggregates

The free moisture content in fine aggregates results in bulking of volume. Due to the bulking, fine aggregate shows completely unrealistic volume. Therefore, it is absolutely necessary that consideration is given to the effect of bulking in proportioning the concrete by volume. This is especially important in Ethiopia where volumetric batching of aggregates is normally experienced in concrete production. If cognizance is not given to the effect of bulking, in case of volume batching, the resulting concrete is likely to be under sanded and harsh. It will also affect the yield of concrete for a given cement content [12].

The finer the sand the more pronounced the bulking. An increase in volume relative to that occupied by a saturated and surface dry sand sharply increases to the extent of 20 and 40 % with a corresponding 4 and 8 % increase in surface moisture [9].Stockpiled coarse aggregate is generally in the air dry (AD) state with an effective absorption of less than 1%. However, fine aggregate is often in the wet state, with a moisture content typically in the range 0 to 5%. The reason for high surface moisture values for the fine aggregate is that in addition to their surface films of moisture, additional water can be held in the interstices between fine particles as a result of formation of menisci [10].

2.5.7.4 Gradation

In order to calculate the proportions of the different ingredients and produce concrete of desired proportions, it is important and indeed required to determine the characteristics of the aggregate which include among other things its gradation. The grading of particle size distribution of aggregate is usually determined by a sieve analysis [9].

A sample of aggregate for sieve analysis is first surface dried and then sieved through the series, starting with the largest. The standard sieve sizes used by some internationally accepted standards are given in Table 2.15. The weight retained on each sieve is recorded and the percentage computed. The summation of the cumulative percentage of the material retained on the sieves (not including the intermediate sieves) divided by 100 is called the *fineness modulus.* It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of gradings which will produce a given fineness modulus [9]. The following limits may be taken as guidance.

Fine sand : F.M. 2.2 - 2.6
Medium Sand : F.M. 2.6 - 2.9
Coarse Sand : F.M. 2.9 - 3.2

A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete [12]. According to literature, for concrete work, the fineness modulus of sand should lie between 2.6 and 3.1 [8].

Table 2.15 Standard Sieves and Square Openings [9]

For Fine Aggregates			**For Coarse Aggregates**		
ES Series	**ASTM Series**		**ES Series**	**ASTM Series**	
Sieve Size & Clear Opening	Sieve Size	Clear Opening	Sieve Size & Clear Opening	Sieve Size	Clear Opening
9.5mm	⅜ in	0.375 in	75 mm	3 in	3.00 in
4.75mm	No 4	0.187 in	63 mm	(2 in)[6]	2.00 in
2.36mm	No 8	0.0937 in	37.5 mm	1½ in	1.50 in
-	-	-	-	1 in	1.00 in
1.18mm	No. 16	0.0469 in	19 mm	¾ in	0.75 in
600µm	No. 30	0.0232 in	13.2 mm	(½ in)[6]	0.50 in
300µm	No.50	0.0117 in	9.5 mm	⅜ in	0.375 in
150µm	No.100	0.0059 in	4.75 mm	No 4	0.187 in

[6] These values called "intermediate" or "full size sieves" are not included in the series for fineness modulus calculations.

Aggregate is graded so as to have different sizes of particles, from the required largest size to the very fine. The use of well - graded mixture of aggregates results in improved workability of the concrete and economy of the cement since such aggregates have a decreased amount of voids between their particles and they consequently require less cement paste [9].

It is reported that, for mixes of given consistence and cement content, a well-graded aggregate produces a stronger concrete than a poorly graded one because less water is required to give suitable workability. In addition, with a given cross sectional dimension of a concrete structural member and spacing of reinforcements, it is in general recommended to select the maximum possible size of aggregate. The maximum size and the grading are important because they affect 1) the relative volume occupied by the aggregate, hence the economy in producing concrete 2) the surface area of the aggregate which determines the amount of water necessary to wet all the solids, 3) the workability of the mixture, 4) the tendency to segregation, and 5) the porosity and shrinkage. This implies that from the point of view of selecting proportions (mix design), it is important to have well graded coarse and fine aggregate with maximum possible size [17].

A suitable gradation of the combined aggregate in a concrete mix is desirable in order to secure workability and to secure economy in the use of cement [8]. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in aggregates. Minimum paste will mean less quantity of cement and less quantity of water, which will further mean increased economy, higher strength, lower -shrinkage and greater durability [12].

For the reason that both the maximum size and grading are important factors to be considered when calculating proportions for concrete mix, national standards specify grading limits for coarse and fine aggregates. According to the Ethiopian Standard ES. C. D3. 20 [16] fine aggregate should consist of natural sand obtained from the natural disintegration of rocks or sand obtained from crushed stones where as coarse aggregate should be gravel, crushed gravel, or crushed stone. In addition, according to the same standard, the fine aggregate should not have more than 45 percent retained between any two consecutive sieves and the fineness modulus should not be less than 2.0 or more than 3.5 with a tolerance of ± 0.2 [16].

The grading or particle size distribution of fine aggregate and coarse aggregate should be with in limits specified in Table 2.16 and Table 2.17 respectively. Standards such as B.S.882 prescribe grading requirements combined or all-in aggregate. These are given in Table 2.18.

Table 2.16 **Grading Requirement for Fine Aggregate** [16].

Sieve size (ES)	ASTM Designation	Percentage Passing
9.5 mm	3/8	100
4.75 mm	-	95 - 100
2.36 mm	No. 8	80 - 100
1.18 mm	No. 16	50 - 85
600 µm	No. 30	25 - 60
300 µm	No. 50	10 - 30
150 µm	No. 100	2 - 10

Table 2.17 **Grading Requirement for Coarse Aggregate** [16].

Sieve Size(ES)	ASTM Designation	Percentage Passing		
		Nominal Size of Graded Aggregate (mm)		
		38[7] - 5	19[7] - 5	13[7] - 5
75 mm	3 in	100		
63 mm	(2 in)	-		
37.5 mm	11/2 in	95 - 100	100	
19 mm	¾ in	30 – 70	95 – 100	100
13.2 mm	½ in	-	-	90 – 100
9.5 mm	3/8 in	10 - 35	25 – 55	40 – 85
4.75 mm	No. 4	0 – 5	0 – 10	0 - 10

Table 2.18 **Grading Requirements for All- In Aggregate (B.S. 882:1954)** [16].

B. S. Sieve Size	Percentage by Weight Passing B.S. Sieves	
	1 ½ in (37 mm) Nominal Size	¾ in (19 mm) Nominal Size
3 in (75 mm)	100	-
1 ½ in (37.5 mm)	95 - 100	100
¾ in (19 mm)	45 - 75	95 - 100
3⁄16 in (4.75 mm)	25 - 45	30 - 50
25	8 - 30	10 - 35
100 (4.75 mm)	0 - 6	0 - 6

[7] The maximum size of an aggregate is defined by the largest sieve through which at least 90% of the aggregates passes.

Divided aggregate is preferable to all - in aggregate for consistent grading and the practical control of quality in concrete manufacture. The various sizes of particles of which an aggregate is composed should be uniformly distributed [15]. Generally, divided aggregate is used in the Ethiopian construction industry.

Standard Grading Curve

When a sieve analysis has been completed, the weight of aggregate retained on each sieve is expressed as a percentage of the total weight of the sample [10]. The results obtained as percent passing or percent retained coarser can be shown graphically in aggregate grading charts. On the horizontal axis are read the sieve openings with arithmetic or logarithmic scale. They are arranged with increasing sieve opening sizes form left to right. On the vertical scale on the left side of the chart are indicated the total percentage coarser, 0 to 100, form bottom to top. The corresponding values for the percentage passing are read on the right side of the chart [9]. However, it is also possible to draw the chart the other way round.

A grading chart is especially useful in checking whether the results obtained from the sieve analysis of a given sample fall with in the limits specified by standards. If, however, they fall outside the limits adjustments must be made. In fact in some places it is difficult to obtain well graded aggregates especially sands. In this case the combined aggregate may be based on what is called gap grading meaning certain sizes are missing. This often happens in places where the coarse aggregate is crushed stone and where only very fine sand is available.

The grading of fine aggregates has much greater effect on workability of concrete than does the grading of coarse aggregate. Experience has shown that usually very coarse sand or very fine sand is unsatisfactory for concrete making. The coarse sand results in harshness, bleeding and segregation, and the fine sand requires a comparatively greater amount of water to produce the necessary fluidity [12].

It is easiest to maintain the uniformity of concrete if the quantities of concrete are to be handled is very large, it may be advantageous to blend several fractions of coarse aggregate to maintain uniform grading. This is a common procedure in ready-mixed concrete plants, due to the reason that concrete can be produced more economically when corrections for grading variability are eliminated [10].

Maximum Size of Aggregates

The maximum size of an aggregate is determined from its sieve analysis and is generally designated by the largest sieve through which atleast 90% of the aggregates pass [8]. The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Using the largest possible maximum possible size will result in (i) reduction of the cement content (ii) reduction in the water requirement (iii) reduction of drying shrinkage.

The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction. For a given quantity of water and paste a bigger size of aggregate will give higher workability [12].

The maximum size of coarse aggregate is governed by the type of work to be done. For reinforced concrete it should be such that the concrete can be placed without difficulty, surrounding all reinforcement thoroughly, particularly in the cover zone, and filling the corners of the formwork. The use of a larger aggregate results in a slightly reduced water demand and hence a slightly reduced cement content for a given strength and workability [11].

Smaller aggregate, usually 10mm maximum size, may be needed for concrete that is to be placed through congested reinforcement for example. In this case the cement content may have to be increased by 10 - 20 % to achieve the same strength and workability as with a 20 mm maximum-sized aggregate concrete because the sand content and water content normally have to be increased to produce a cohesive mix [11].

2.5.7.5 Physical Properties

With respect to physical properties, coarse aggregates should comply with the following characteristics [15].

(i) Abrasion-resistance
(ii) Aggregate crushing value
(iii) Aggregate impact value

2.5.7.6 Shape

The shape of aggregate is an important characteristic since it affects the workability of concrete. The shape of the aggregate is very much influenced by the type of crusher and the reduction ratio, ν, i.e., the ratio of the size of material fed into crusher to the size of the finished product [12]. Particle shape and size distribution influence the water content necessary to obtain a mix of suitable resistance, and then by affecting the compressive strength, drying shrinkage and durability of the resulting concrete. Inaddition, the sum of the flakiness and elongation indices should not exceed 40% or 35% in some standards[15]. Description and examples of different classes of shapes of aggregates are given in Table 2.19.

Particle shape of aggregates can be calculated by one of the following methods:

(i) Thickness and length guages
(ii) Proportion Calliper
(iii) Angularity number

From the standpoint of economy in cement requirements for a given water/cement ratio, rounded aggregates are preferable to angular aggregates. On the other hand, the additional cement required for angular aggregate is offset to some extent by the higher strength and sometimes by greater durability as a result of the inter- locking texture of the hardened concrete and higher bond characteristic between aggregate and cement paste [12].

Table 2.19 Shape of Particles [12].

Classification	Description	Examples
Rounded	Fully watered worn or completely shaped by attrition	River or seashore gravels; desert, seashore and wind-blown sands
Irregular or partly rounded	Naturally irregular, or partly shaped by attrition, having rounded edges	Pit sands and gravels; land or dug flints; cuboid rock
Angular	Possessing well-defined edges formed at the intersection or roughly planar faces	Crushed rocks of all types; talus; screes
Flaky	Material usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

2.5.7.7 Texture

Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it. It has been also shown by experiments that rough textured aggregate develops higher bond strength in tension than smooth textured aggregate [12]. The summary of these experiments is shown in Table 2.20.

Table 2.20 Influence of Texture on Strength [12].

Percent of particles		Water/ Cement Ratio	Strength, 28 days Kg/cm^2	
Smooth	**Rough**		**Flexural**	**Compressive**
100	0	0.54	43	348
50	50	0.57	46	321
0	100	0.60	48	295

2.5.7.8 Strength

When cement paste of good quality is provided and its bond with the aggregate is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of the concrete. Therefore, it can be concluded that while strong aggregates can not make strong concrete, for making strong concrete, strong aggregates are essential requirement [12]. Assessment of strength of the aggregate is made by using a sample of bulk aggregate in a standardized manner. This test is known as aggregate *crushing value test*. Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load [12].

2.5.7.9 Aggregate Impact Value

Apart from testing aggregate with respect to its Crushing Value and impact resistance, testing the aggregate with respect to its resistance to wear is an important test for aggregate to be used for road constructions, ware house floors and pavement constructions. Specified abrasion change and abrasion and crushing value percentage limits are given in Table 2.21 and Table 2.22 respectively. Three tests are in common use to test aggregates for its abrasion resistance [12]. (i) Deval attrition test (ii)Dorry abrasion test (iii) Los Angeles test

Table 2.21 Specified Abrasive Change [12].

Grading	Number of spheres	Weight of change (gm.)
A	12	5000±25
B	11	4585±25
C	8	3330±20
D	6	2500±15

Table 2.22 Abrasion and Crushing Value Percentage Limits [15]

Aggregate Type	Los Angeles Value	Aggregate Crushing Value
Hornfels	25	20
Andesite; Basalt	30	25
Breccia; Dolerite	30	25
Microdiorite; Microgranite	30	25
Microsyenite; Rhyolite	30	25
Limestone; Quartzite	35	30
River Gravel; Slate	35	30
Granite; Quartz	45	40

The average values of different tests on Rocks of different groups are summarized in Table 2.23.

Table 2.23 Average Test Values for Rocks of Different Groups [12].

Rock Group	Crushing Strength (Kg/cm^2)	Aggregate Crushing Value (%)	Abrasion value	Impact value	Attrition Value		Specific gravity
					Dry	Wet	
Basalt	2070	12	17.6	16	3.3	5.5	2.85
Flint	2143	17	19.2	17	3.1	2.5	2.55
Gabbro	2036	-	18.7	19	2.5	3.2	2.95
Granite	1929	20	18.7	13	2.9	3.2	2.69
Gritstone	2286	12	18.1	15	3.0	5.3	2.67
Hornfels	3536	11	18.8	17	2.7	3.8	2.88
Limestone	1714	24	16.5	9	4.3	7.8	2.69
Porphyry	2393	12	19.0	20	2.6	2.6	2.66
Quartzite	3391	16	18.9	16	2.5	3.0	2.62
Schist	2536	-	18.7	13	3.7	4.3	2.76

2.5.7.10 Modulus of Elasticity

Modulus of elasticity of aggregate depends on its composition texture and structure. The modulus of elasticity of aggregate will influence the properties of concrete with respect to shrinkage and elastic behavior and to very small extent creep of concrete [12].

2.5.8 Durability of Aggregates

Since aggregates make up the bulk of concrete, any lack of durability of the aggregate will have disastrous consequences for the concrete. If there are durability problems, special screening tests may be required, routinely to avoid problem aggregates, or special measures must be taken to counter act the effects of undesirable aggregates. The latter approach will become more important in the future as deposits of high-quality aggregates are worked out and more marginal material is brought into use [10].

Aggregates should be hard and should not contain materials that are likely to decompose or change in volume when exposed to weather. Examples of undesirable materials are lignite, coal, pyrite and lumps of clay [11].

2.5.8.1 Chemical Reactions

For a long time aggregates have been considered as inert materials but later on, particularly, after 1940's it was clearly brought out that aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalis present in cement i.e. sodium oxide and potassium oxide [12]. The formation of the products of the reaction between the alkalis and the aggregate causes abnormal expansion, which, however, sometimes doesn't take place until two or more years after the concrete has been placed [8].

The types of rocks which contain reactive constituents include traps, andesites, rhyolites, siliceous limestones and certain types of sandstones. The reactive constituents may be in the form of opals, cherts, chalcedony, volcanic glass, zeolites etc. The reaction starts with attack on the reactive siliceous minerals in the aggregate by the alkaline hydroxide derived from the alkalis in cement. As a result, the alkali silicate gel of unlimited swelling type are formed. When these conditions are congential, progressive manifestation by swelling takes place, which results in disruption of concrete with the spreading of pattern cracks and eventual failure of concrete structures. The rate of deterioration may be slow or fast depending up on the conditions [12].

The following are factors which promot the alkali - aggregate reaction

(i) Reactive type of aggregate
(ii) High alkali content in cement
(iii) Availability of moisture
(iv) Optimum temperature conditions

Many specifications restrict the alkali content to be less than 0.6 percent expressed as soda equivalent. A cement meeting this specification is designated as a low alkali cement. Field experience has never detected serious deterioration of concrete through the process of alkalis less than 0.6 percent. In exceptional cases, however, cements even with lower alkali content have caused objectionable expansion [12].

Evaluation of aggregates for potential damage due to alkali- aggregate reaction requires judgement based past service record of the aggregate source, if available, and possible use of one or more laboratory procedures such as C295 for petrographic examination, C227 for mortar bar expansion of the aggregate used with cement, and the quick chemical method C289. In some cases, one or more of the tests will indicate potential reactivity, but if the source has good service record for a long period of time in a similar environment, and if the aggregate in such concrete is petrographically similar to the aggregate under evaluation, it may be acceptable for use, particularly with a low –alkali cement.

Use of certain pozzolanas, blended cements, or slag cement may be sufficient to eliminate the risk of deleterious alkali-aggregate reaction and may be determined by ASTM C441 [34]. One materials testing laboratory in Addis Ababa has all the laboratory equipments necessary to carry out all the three test methods mentioned above. However, it is complained that the number of test samples submitted for assessement of potential alkai-aggregate reaction is too small.

2.5.8.2 Soundness

Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These physical conditions are the freezing and thawing, variation in temperature, alternate wetting and drying in salt water. Aggregates which undergo more than the specified amount of volume change are said to be unsound aggregates [12].The disintegrative resistance to an aggregate to sulphate solution is a means of estimating its soundness to weathering action, particularly where relevant service records are inadequate or unavailable [15].

2.5.8.3 Deleterious Substances/Cleanliness

The concrete aggregate should be free from impurities and deleterious substances that are likely to interfere with the process of hydration and results in prevention of effective bond between the aggregate and matrix. These impurities sometimes reduce the durability of the aggregate. Generally, the fine aggregate obtained from natural sources is likely to contain organic impurities in the form of silt and clay. The manufactured fine aggregate doesn't normally contain organic materials. But it may contain excess of fine crushed stone dust. Coarse aggregate stacked in the open and unused for long time may contain moss and mud in the lower level of the stack [12]. Limits of deleterious substances in concrete aggregates are given in Table 2.24.

Sometimes excessive silt and clay contained in the fine or coarse aggregates may result in increased shrinkage or increased permeability in addition to poor bond characteristics. The excessive silt and clay also necessitates greater water requirements for given workability. The quantity of clay, fine, silt and fine dust are determined by sedimentation method. To ascertain whether a sample of fine aggregate contains permissible quantity of organic impurities or not, a simple test known as colorimetric test is made [12].

Table 2.24 Limits of Deleterious Materials [12].

Deleterious Substance	**Fine Aggregate**		**Coarse Aggregate**	
	Uncrushed	**Crushed**	**Uncrushed**	**Crushed**
Clay and Lignite	1.00	1.00	1.00	1.00
Clay Lumps	1.00	1.00	1.00	1.00
Soft fragments	-	-	3.00	-
Material passing 75 micron IS sieve	3.00	3.00	3.00	1.00
Shale	1.00	-	-	-

Note : The sum of the percentage of all deleterious material shall not exceed five.

Aggregates should be clean and free from organic impurities: aggregate containing organic material makes poor concrete. The particles should also be free from coatings of dust of clay, as these prevent the proper bonding of the material. An excessive amount of fine dust or stone 'flour' may prevent the particles of stone from being properly coated with cement and thus lower the strength of the concrete [11].

Gravels and sand are sometimes washed by the suppliers to remove excess fine (clay and silt, for example) and other impurities, which, if present in excessive amounts, result in a poor quality concrete. However, excessive washing can remove all fine material passing the 300μm sieve. This may result in a concrete mix lacking in cohesion and, in particular, being unsuitable for placing by pump. Sand deficient in fines also tends to increase the bleeding characteristics of the concrete, which can result in poor vertical finishes due to water scour [11].

2.5.9 THERMAL PROPERTIES

Rock and aggregate possess three thermal properties which are significant in establishing the quality of aggregate for concrete construction. They are [12]:

(i) Coefficient of expansion

(ii) Specific heat

(iii)Thermal conductivity

Out of the three, specific heat and conductivity are found to be important only in mass concrete construction where rigorous control of temperature is necessary. Also these properties are of consequence in case of light weight concrete used for insulation purpose. When dealing with the aggregate in general it will be sufficient to deal with only the coefficient of expansion of the aggregate, since it interacts with the coefficient of thermal expansion of cement paste in the body of the set-concrete [12]. The coefficient of thermal expansion of concretes made with different aggregates is given in Table 2.25.

Table 2.25 Coefficient of thermal expansion of 1:6 concretes made with Different Aggregates [12].

Type of aggregate	Linear coefficient of thermal expansion		
	Air-cured concrete 10^{-6} per ^{0}C	**Water-cured concrete 10^{-6} per ^{0}C**	**Air cured and wetted concrete 10^{-6} per ^{0}C**
Gravel	13.1	12.2	11.7
Granite	9.5	8.6	7.7
Quartzite	12.8	12.2	11.7
Dolerite	9.5	8.5	7.9
Sandstone	11.7	10.1	8.6
Limestone	7.4	6.1	5.9
Portland stone	7.4	6.1	6.5
Blast-furnace slag	10.6	9.2	8.8
Foamed slag	12.1	9.2	8.

If a particular concrete is subjected to normal variation of atmospheric temperature, the thermal incompatibility between the aggregates and the paste or between the aggregate and matrix may not introduce serious differential movement and break in bond at the interface of aggregate and paste or aggregate and matrix. But if a concrete is subjected to high range temperature difference the adverse effect will become acute. In dealing with the fire resistance of concrete the study of coefficient of thermal expansion of aggregate is also important [12].

Coefficient of thermal expansion of concrete at high temprature is given in Table 2.26 and the influence of aggregate on the coefficient of thermal expansion is given in Table 2.27.

Table 2.26 Coefficient of Thermal Expansion of Concrete at High Temperatures [12].

Curing condition	Water/ cement ratio	Cement content Kg/m³	Aggregate	Linear coefficient of thermal expansion at the edge of			
				28 days		90 days	
				Below 260°C 10^{-6} per °C	Above 430°C 10^{-6} per °C	Below 260°C 10^{-6} per °C	Above 430°C 10^{-6} per °C
	0.4	435		7.6	20.3	6.5	11.2
Moist	0.6	310	Calcareous	12.8	20.5	8.4	22.5
	0.8	245	Gravel	11	21.1	16.7	32.8
Air	0.4	435		7.7	18.9	12.2	20.7
50 %	0.6	310	Calcareous	7.7	21.1	8.8	20.2
relative	0.8	245	Gravel	9.6	20.7	11.7	21.6
humidity							
Moist air	0.68	355	Expanded	6.1	7.5	-	-
	0.68	355	Shale	4.7	9.7	5.0	8.8

Table 2.27 Influence of Aggregate Content on the Coefficient of Thermal Expansion [12].

Cement/Sand ratio	Linear coefficient of thermal expansion Of concrete at the age of 2 years 10^{-6} per °C
Neat cement	18.5
1:1	13.5
1:3	11.2
1:6	10.1

2.5.10 Aggregate Beneficiation

If an aggregate doesn't meet the specifications required for the job, the concrete producer is faced with two courses of action. One option is to reject the aggregate or the other is to consider taking measures to bring the aggregate up to specifications. Beneficiation of aggregate may be the only available solution if aggregate supplies are scarce, but it will add to cost of the aggregate and hence of the concrete [10].

2.5.11 EFFECTS OF CONCRETE MAKING MATERIALS ON THE PROPERTIES OF HARDENED CONCRETE

2.5.11.1 Shrinkage of concrete

In ordinary concrete the weakest phase is the cement paste, hence, aggregate strength is of minor importance. However, aggregates make up the highest percentage of those materials used for making concrete, and as a consequence their properties, other than strength, affect the characteristic of concrete, both in the plastic and in the hardened state [9].

When stored in an unsaturated air, concrete losses part of its water content through evaporation. This withdrawal of water starts while the concrete is still in a fresh or plastic state and continues for several days and months after the concrete has hardened. The corresponding dimensional changes are known as plastic and drying shrinkage [9].

The mineral composition, grading and mechanical properties of aggregates constitute one of the few if not the most important factors on the shrinkage of concrete. The mineral composition of aggregates is important because under comparable conditions, minerals behave differently when alternately wetted and dried. The maximum size and grading of aggregates influence the magnitude of shrinkage indirectly. Well graded aggregates with a large maximum size have a low void space and permit the use of a leaner mix, larger maximum size aggregate also allows lower water content, consequently both effects result in a lower shrinkage [9].

Shrinkage of concrete as influenced by mix proportions made with different aggregates is given in Figure 2.2. As is it shown in the picture concrete made with quartz aggregates has the least shrinkage when compared to concrete made with other types of aggregates.

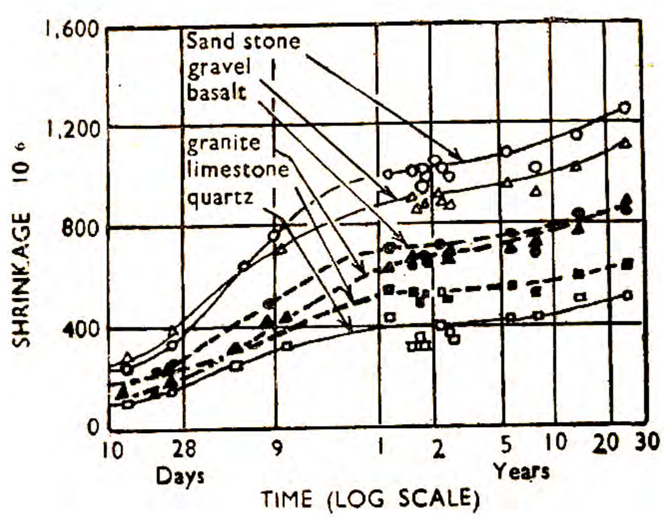


Fig 2.2 Shrinkage of concretes of fixed mix proportions made with different aggregates and stored in air at 20 °C and a relative humidity of 50 percent [12].

2.5.11.2 Strength of Concrete

For a constant water cement ratio and the same degree of compaction, the compressive strength of concrete decreases when the specific surface of the aggregate increases. And if, for the same cement content and degree of compaction, the quantity of fine is increased, the demand for higher amount of water arises and consequently, leads to a weaker concrete . Test results reported by Portland Cement Association indicates that the 28 day strength of concrete of given consistence increases with fineness modulus of the mixed aggregate provided the limits of workability are not exceeded [9]. Table 2.3 shows the effect of aggregate/cement ratio on strength of concrete.

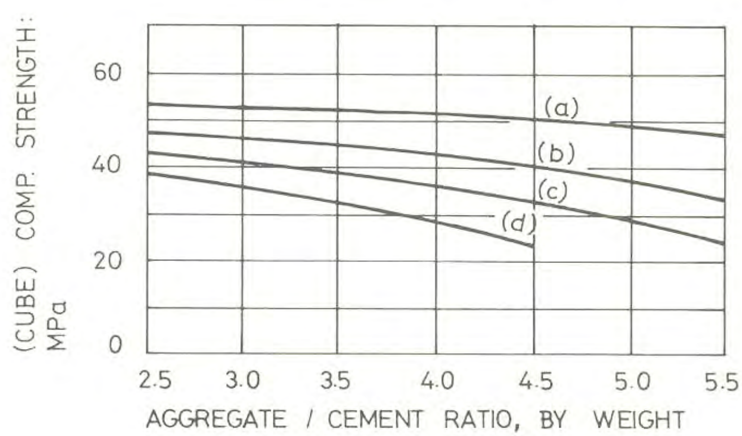


Fig 2.3 Effect of aggregate/cement ratio on strength (curve a represents a very stiff mix and curve d represents a plastic mix)

2.5.12 Handling of Concrete Making Materials in Construction Sites

Materials handling is not merely a site problem; it is affected by the designer, the manufacturer and the contractor. Unnecessary handling of materials increases site costs, and yet often materials waste could be reduced by redirecting under-employed plant and equipment [7].

2.5.12.1 SOURCE

a. Fine Aggregate

To ensure that the proper amount of sand is present, the separate delivery, storage and batching of coarse and fine aggregate is essential [11]. Uniform concrete requires a consistent source, character, grading and moisture content of fine aggregate. In addition, segregation of aggregate moving down a sloping surface can be prevented by a retaining baffle. 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 [15]. Processes involved in a modern sand production is shown in Fig. 2.4.

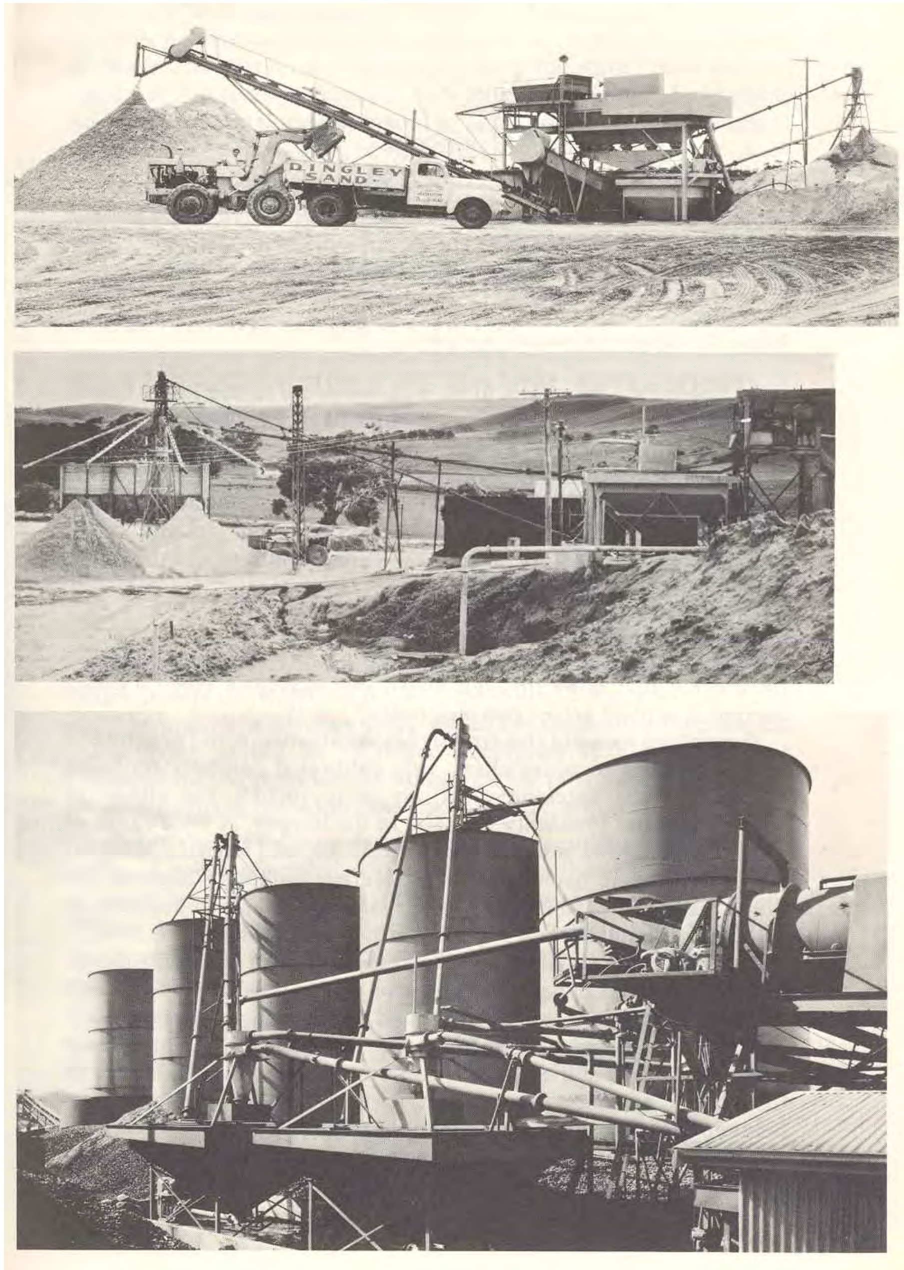


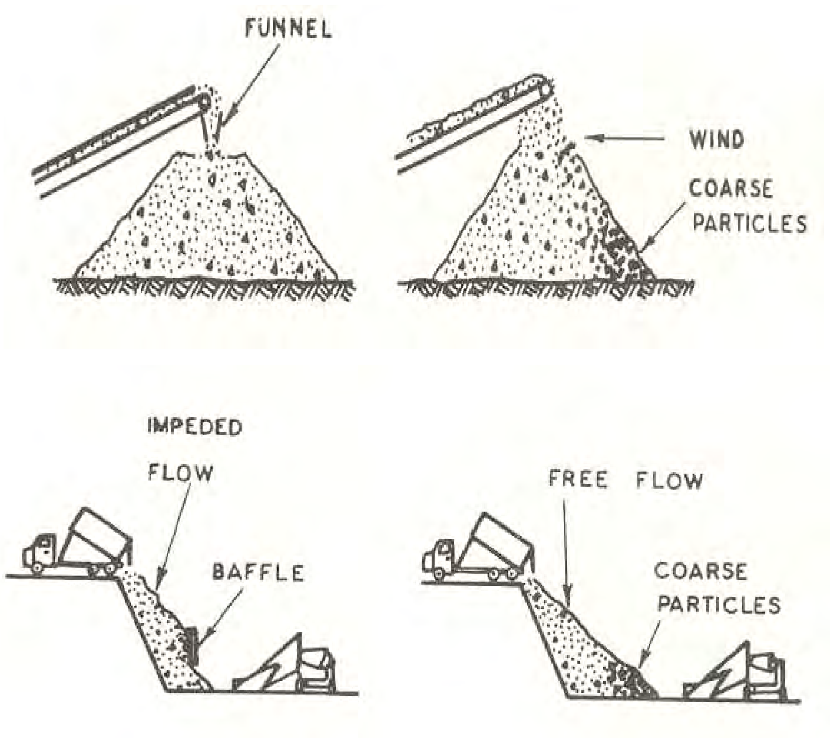
Fig 2.4 Modern Sand Processing (Plant operations include screening, washing, separation and fractional classification.) [15]

Beach sands 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 [11].

b. Coarse Aggregate

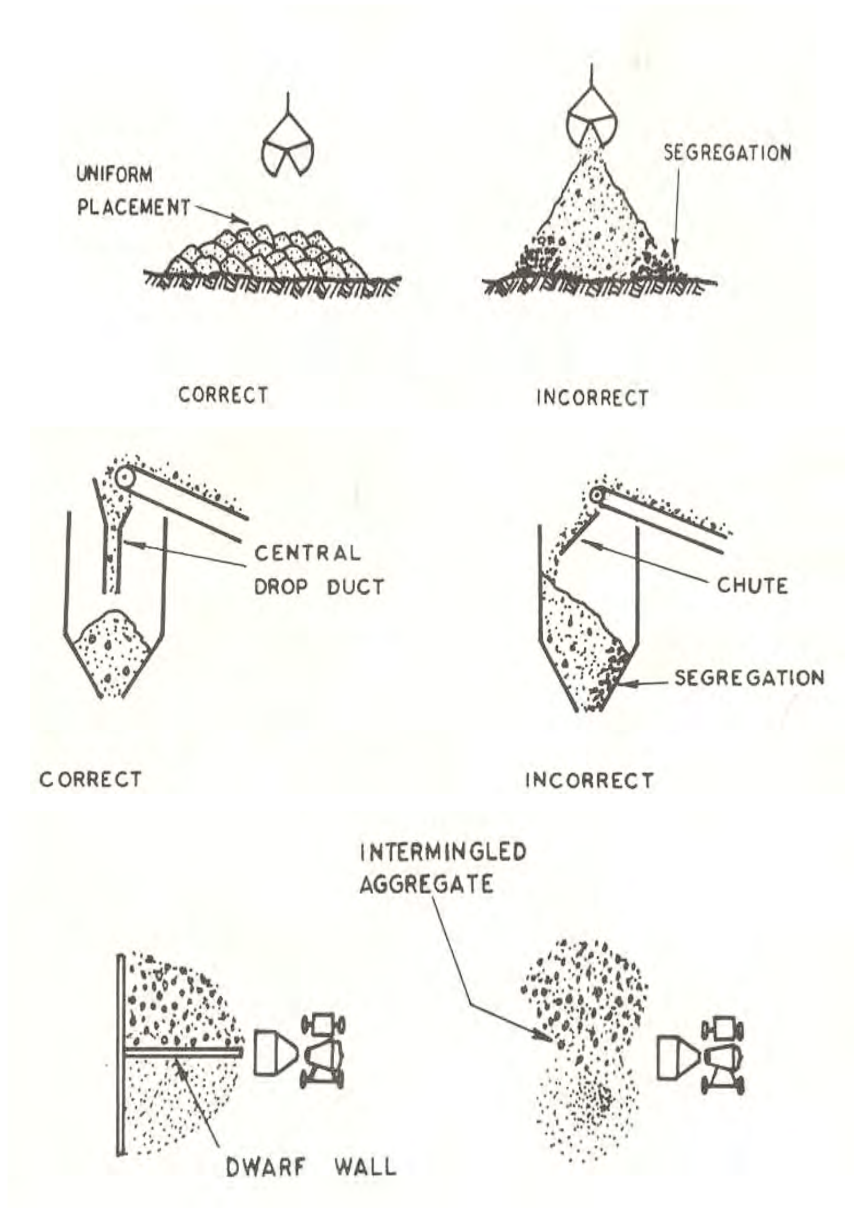
For a high degree of control over the production of concrete, it is necessary for the coarse aggregate to be delivered, stored, and batched using separate single sizes rather than a graded coarse aggregate [11]. The preparation of crushed rock or crushed stone aggregate at the quarries requires several steps which include the blasting of the rock which is conveyed by belt conveyor to the crushing plant. The crusher, which could be of different type, is generally adjusted so as to give a range of aggregate sizes. The output is made to pass over a set of screens and the different fraction sizes collected for sale [9].

For uniform concrete, coarse aggregate is separated into several size fractions or gauges. Bulk storage should be on hard ground or a thin slab of weak concrete that is graded for drainage. A space or dwarf walls should be placed between different materials. When stock piles are required, they should be built up in horizontal or gently sloping layers and not by end-dumping methods [15]. Correct and incorrect method of aggregate handling are shown in Fig 2.5.



Correct Incorrect

Fig 2.5 Methods of Aggregate Handling [15].



Correct Incorrect

Fig 2.5 Cont. Methods of Aggregate Handling [15].

2.5.12.2 Delivery of Cement and Aggregates

Materials are delivered to the site in many forms; some will be in bulk or even bagged, while others are crated, packaged or in pallet form. Obviously this affects distribution and storage on site, and while large quantities will be delivered in bulk, small quantities or mixed amounts are more likely to be delivered loose. Bulk deliveries include hardcore, aggregate, PFA (Pulverized Fuel Ash), bituminous paving materials, concrete and cement [7].

Cement is generally transported, off-loaded, stored and withdrawn from storage before it can be used. Road vehicles for transporting cement in bulk include tipping lorries, air -assisted discharge lorries fitted with spiral-type discharge conveyors and vehicles fitted with bottom-emptying hoppers or pressure containers [15].

Cement may be delivered in bulk or in bags. Bulk cement is delivered by tanker, usually in loads of more than 25 tones and blown into storage silos by compressed air. Cement is normally supplied in bags containing 50 kg in Ethiopia. It is often convenient to use bags on a smaller site, but cement is cheaper in bulk [11]. For instance, there is a 1 birr per quintal saving in buying cement in bulk from Mugher cement factoryin Ethiopia.

Unless care is taken in handling and storing of aggregates, there is a marked tendency for segregation of the fine and coarse particles to occur. In general, there is less danger of segregation in coarse aggregates if they are screened into two or more size ranges and handled separately [8].

Segregation is more serious in all-in-aggregates or course aggregate which contains different sizes. In general, there is less danger of segregation, especially in coarse aggregate, if it is prepared or split into size fractions (i.e. 13-5, 19-5, etc.) and stockpiled separately and remixed in the desired proportions when the concrete is prepared [9].

2.5.12.3 Receiving

The simplest and presumably the cheapest method of unloading materials has been to tip them directly where they are to be used, and with aggregates, hardcore and excavated materials this can still be done with out detracting from the quality. These materials offloaded by direct tipping are usually transported in trucks with elevated sides [7].

Quality control of concrete should start with a visual inspection of the aggregates as they are delivered, combined with some quick, simple testing if there is any doubt about their quality or grading. The cleanness of sand can be checked quickly by hand. If a sample of sand is rubbed between the palms of the hands, staining of the palms may be an indication of that an excessive amount of clay and silt are present, due to in adequate washing [11].

Coarse aggregates should be inspected visually for clay lumps and clay coatings grading and particle shape. Clay lump are not always obvious and careful inspection of deliveries is advised. Loads containing such lumps should be rejected before discharge [11].

2.5.12.4 Storage

Cement should be kept dry during storage as moist air leads to the phenomenon of air-setting, which results in the formation of lumps of hydrated cement. Air-set cement should not be used, as concrete made from it could have a much reduced strength. Silos have to be weatherproof but, during prolonged periods of storage, some air setting may occur due to condensation in the silo. This is minimized by aeration, which should be done frequently in periods of prevailing damp weather. Regular maintenance of cement silos is essential [11].

At all stages up to the time of use, cement must be kept dry so as to prevent or minimize deterioration from the effects of moisture, atmospheric humidity and carbonation. Air tight drums and internally coated bulk silos are ideal storages. Cement in multi-wall paper bags should be stored in a water proof building with close-fitting doors which should be kept closed as much as possible. The floor should be placed well above the ground and incorporate a vapor proof membrane so as to keep it dry. If this is not possible, the bagged cement must be stacked on pallets or on a dry board platform, some 150mm clear of the surface. The roof should be pitched as a slope of 1 in 3, so that condensation drips will not fall. In regions of high relative humidity, insulation and a storage temperature of 45 ^{0}c are advisable [15].

Bags of cement should be stacked close together, so as to restrict the circulation of air around them. The stacks should be kept 150 - 300 mm clear of the walls (with access ways 900 mm wide). Stacks that are more than eight bags high should be placed in header and stretcher formation, so as to increase their stability when laid up to the maximum height (for economic handling) of 4.2 m. Tall stacks are stepped back for stability when cement is being withdrawn [15].

Cement which is 4 months old should be classified as "aged" and be retested before use. The capacity of bulk-storage containers should excess the requirements of cement for 1 week and they should be cleared out as least once each 4 months. For full strength development, the cement should be used with in 3 months [15].

The bags should be used in the order in which they are received; thus each delivery should be kept separate to avoid confusion. Paper bags used for packing cement are not vapor proof, so undue exposure should be avoided. Even when stored under good conditions, bagged cement may lose 20% of its strength after two months' storage. In addition, to avoid risk of accidental confusion, cements of different types should be stored separately [11].

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 on bay to another [11].

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 form 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 large batching plants the aggregate would probably be lifted by a conveyor system to covered overhead storage hoppers discharging directly into weigh-batchers [11]. Aggregate for concrete will be stored in a central area.

2.5.12.5 Materials Control on Site

Control of the materials used on site begins the time the contractor is handed over the site. All materials delivered to site must be compared with the relevant standards. Besides the general waste of materials on site, there is a lot of damage, and this is often due to lack of proper supervision. Responsibility for materials must begin with the person handling them.

Many foremen and supervisors see their main function as that of materials supplier to the group they are responsible for, ignoring materials handling. If a materials controller is appointed to anticipate materials requirement and distribute supplies, trades foremen will have enough time to do their job properly. Site management is ultimately responsible for materials use and handling [7]. Materials may be kept on site over long or short period of time until they are needed. Storage also means expenditure of capital, and money and contractors are reluctant to purchase materials in advance, except for those needed almost immediately [7]. Summary of the proper control of materials at every stage of operation is shown in Table 2.28.

Table 2.28 Proper control of materials requires controlled supervision at every stage of operations [7].

Materials	Handling	Storage	Protection	Loss or Waste
Fine & Coarse Aggregates	-Delivered by high-sided truck -Check quality, grade and quantity -Transfer by grab, mechanical shovel or power-assisted equipment on weigh batcher -Transport by bucket, hopper, dumper and barrow.	In prepared bays adjacent to mixer. In selected grading and particular size. On concrete base laid to falls.	-Cover against frost, snow or rain -Avoid contamination with mud, clay or oil -Install steam heating to base of mound -Check calibrations on weighting equipment	-Indiscriminate handling -Contamination of any kind -Failure to trim stocks -Using as site dressing or to fills site voids
Cement	-Delivered by tanker and pumped into silo -Delivered in 50 kg paper sacks on timber pallets -Offload by forklift or crane -Use bagger cement in order of delivery	-In special silo adjacent to mixer -On raised platforms in shed or in open -Covered completely with tarpaulin or polyethylene sheet	-Avoid accidental bursting of sacks -Restrict raising moisture affecting cement in store -Cover against rain, snow and ice	-Humidity causing materials to damp -Dumpiness initiating set -Indiscriminate handling causing bags to burst -Failure to use deliveries in rotation -Pilfering -Leaving stocks unused

2.5.12.6 Stockpile arrangements

Stockpiles must be pre-planned as short-term storage areas, each one selected for its strategic relationship to one or more sectors of the site. Withdrawal of materials should be monitored so that stockpiles can be balanced regularly. There must be a recognized and easily applied system for withdrawing materials from the stockpile [7].

Materials should be stacked so that access to other components is not obstructed, and mechanical equipment can be operated without additional manual assistance. Cement should be stacked on a timber platform in moisture-free conditions, and stocks withdrawn in rotation to prevent the materials being kept too long. Burst bugs should be used first, but materials affected in any way by moisture can not be used, particularly where cement is required for 'design mixes.' Large deliveries of cement will normally be stored on site within a site included with the cement concrete paste [7].

2.5.12.7 General Preparation

Materials are consistently 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, which is a very strong reason for preparing the area beforehand. Topsoil should be removed and set aside for re-use 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 [7].

2.5.12.8 Protection

Construction materials and components are rarely given the degree of protection they need to perform in accordance with the specification. Usually this is because site personnel do not understand the possible problems that can arise. Physical attack on materials and components can be dealt with relatively 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. Aggregate stored in a mixing area is shown in Figure 2.5.

Fig 2.6 Aggregate for concrete stored in a mixing area [7].

Of all the construction materials, none can have been treated with more indifference over the years than Ordinary Portland Cement. OPC is hygroscopic, it absorbs moisture from the air, setting off a chemical reaction which affects the molecular structure and reduces the subsequent strength. In addition, unless aggregates are stored on a properly prepared site they are likely to become contaminated with mud or clay, which will obviously affect the strength of the concrete mix [7].

2.5.12.9 Waste in Handling

There is more waste of some materials than others; on most sites it would be difficult to decide which materials were worst affected, bricks, blocks, concrete or mortar, although the waste from bagged plaster and cement has always been exceptionally high. Whenever concrete is used in large quantities it is wasted and one reason for that is the quantities required have been miscalculated [7].

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 [7].

Materials waste can be classified as loss through poor site security, inefficient handling, inadequate storage, and misuse in construction or manufacture, or all of which point to poor management. Where the losses occurs at site level then it is site control which must be improved, and this must be more effective where support is available from head office management. Plans can be made at head office or at site management level, but implementation can only be achieved by general cooperation at site level [7].

Waste occurs on site for a number of reasons, most of which can be prevented. Some of the most obvious ones are:

- misinterpretation of drawings;
- overestimating the quantities required;
- faulty workmanship;
- careless handling of materials.

Materials are also wasted by design requirements. The preparation and use of materials inevitably creates a certain amount of waste, and this can be assessed in advance. Any increase should be investigated to avoid a recurrence. While poor design contributes to materials waste, it is often the quality of craftsmen which determines the extent of such waste. Waste can occur through shortages in the materials delivered to site [7].

Much of the problem lies in the abundance of and relative cheapness of materials in the past. Planning approval is now required before erecting plant or opening up quarries; Health and Safety at Work legislation necessitates expensive labor and machinery, and increased running costs; more stringent controls on waste disposal have to be complied with; and even when the materials have been won it is necessary to reinstate the area to satisfy environmental regulations [7].

The answers to many of these problems can be found in better controls. One solution is to appoint a materials controller with defined responsibilities for all materials on site, and sufficient authority to enforce control procedures. This will save materials and money [7].

2.5.12.10 Batching

One important aspect in handling of concrete making materials is the method used in batching these materials. For normal batching, cement should be measured by the bag unless fractional bags are weighed [15]. However, fine and coarse aggregates can be batched gravimetrically, manually or volumetrically. Since cement is delivered in bags there is no problem in batching cements in Ethiopia.

a. Gravimetric Batching

Each type or size of aggregate should be stored and weighed separately, weighing being to a tolerance of 2% individually or 1% cumulatively on a standard, surface dry basis [15].

b. Manual Batching

Wheel barrows and platform scales are satisfactory and economical for projects that require up to 1000m^3 of concrete [15].

c. Volumetric Batching

Volumetric batching on small-job sites is done with cuboid gauge boxes, which are screened off level for uniformity in filling. If fractional bags of cements are used, an allowance must be made for the increase in volume of the cement, due to aeration by disturbance. Batches should be so arranged in size that whole bags of cement are employed. Nominal proportions of mix refer to dry materials. When gauging moist sand by volume, a correction is necessary for bulking due to moisture content, which causes sand to occupy a larger volume than it would if it were dry. The volume of coarser aggregate stays fairly constant whether it be dry, moist or wet [15]. In most construction projects in Ethiopia, volumetric batching using wooden or steel boxes is carried out.

2.5.13 SAMPLING OF AGGREGATES

The object of sampling is to produce a truly representative quantity of the consignment being sampled and of sufficient quantity for the tests required [11]. Samples should show the true nature and condition of the materials they represent. They should be drawn from points known to be representative of the probable variations in the material. A bulk sample is obtained by combining a sufficient number of increments that are drawn from different parts of the bulk [15].

2.5.13.1 Samples and Sampling Methods

Sampling is equally as important as testing and the sampler shall use every precaution to obtain samples that will show the nature and condition of the materials which they represent. Samples for preliminary investigation tests are obtained by the party responsible for development of the potential source (if aggregate source is to be developed[8]) or responsible construction party (if it is for mix-design purpose). Samples of materials for control of the production at the source or control of the work at the site of use are obtained by the producer, contractor or other parties responsible for accomplishing the work.

The fineness modulus of a well-graded sand should not vary by more than ± 0.2 from that of a preliminary representative sample. When dry sand is dropped from the end of an elevated conveyor, a chute or a chimney should be installed so as to prevent a segregation of sizes by wind action [34].

2.5.13.2 Securing Samples

Where practicable, samples to be tested for quality should be obtained from the finished product. Samples from the finished product to be tested for abrasion loss shall not be subject to further crushing or manual reduction in particle size in preparation for the abrasion test unless the size of the finished product is such that it requires further reduction for testing

[8] The preliminary investigation and sampling of potential aggregate sources and types occupies a very important place in determining the availability and suitability of the largest single constituent entering into the construction. It influences the type of construction from the standpoint of economics and governs the necessary material control to ensure durability of the resulting structure, from the aggregate standpoint. This investigation should be done only by a responsible trained and experienced person.

purposes. The material shall be inspected to determine noticeable variations. Sampling can be from one of the following sources:

a. Sampling from a Flowing Aggregate Stream (Bins or Belt Discharge)

b. Samples from the Conveyor Belt

c. Sampling From Stock Piles or Transportation Units

Maximum normal size of aggragtes and the respective approximate minimum mass of field samples is given in Table 2.29.

Table 2.29 Size of Aggregate Samples (ASTM D75 - 82)

Maximum Normal Size of Aggregates[9]	Approximate Minimum Mass of Field Samples [10] (Kg)
Fine Aggregates	
2.36mm	10
4.75mm	10
Coarse Aggregates	
9.5mm	10
12.5mm	15
19.0mm	25
25.0mm	50
37.5mm	75
50mm	100
63mm	125
75mm	150
90mm	175

2.5.13.3 Shipping Samples

- Transport aggregates in bags or other containers as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.
- Shipping containers for aggregate samples shall have suitable individual identification attached and enclosed so that field reporting, laboratory logging, and test reporting may be facilitated.

[9] For processed aggregate the normal maximum size of particles is the largest sieve size listed in the applicable specification, upon which any ,material is permitted to be retained.

[10] For combined coarse and fine aggregates minimum weight shall be course aggregate minimum plus 10kg.

2.6 PRODUCTION PROCESSES OF CONCRETE MAKING AGGREGATES

2.6.1 FINE AGGREGATE PRODUCTION

Sand plays a critical role as a concrete aggregate and it deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers can be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion.

Whichever size the producer decides to eliminate for quality reasons obviously also will affect sizing. Good quality natural sand is available in many areas and may be easy to obtain and process. The sand deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table differs in fines content and quality from that found above the water table. How fine aggregate is produced in Ethiopia and in Germany is discussed in chapter 3.

2.6.2 PRODUCTION METHODS OF COARSE AGGREGATES

With the exception of manufactured aggregates, most materials for aggregate production come from bedrock or unconsolidated deposits. A quarry can be established as a suitable outcropping, or overburden may need to be removed before the rock is exposed .

Crushed stone aggregates are produced from many natural deposits including; limestone, granite, trap rock and other durable mineral resources. Production of these materials requires blasting and excavating the broken stone from quarries followed by progressive stages of crushing, screening, washing and blending. The numerous sizes and gradations are determined by their intended use and each complies with the specifications established by governmental agencies or customer's requirements. Production of coarse aggregates from rocks involves different processes including stripping, drilling, blasting, crushing and screening.

2.6.2.1 STRIPPING

At this step, the producer should spell out a detailed stripping for each and every deposit it mines. This phase is often overlooked, yet it has a great influence on the quality and variability of the product. Inadequate removal of overburden from the mineral deposit often can be the source of excessive variation.

2.6.2.2 DRILLING AND BLASTING

Except where unconsolidated deposits are being worked out, such as old river-beds, which are a source of boulders, gravel and sand, the first operation in the production of aggregates is blasting. Depending on the requirements of each operation and specifically the blasting pattern, blasting results in a spread of loose rock ranging in size from typically 400mm to zero, although the top-size of the run-of-mine ore can be up to one or two meters.

Quarry operators commonly design fragmentation shots for safety, economy, ease of use at the primary crusher, and even public relations, but they often forget about quality. It is important that the shot layout be properly engineered, documented, and adhered to for maximum consistency. Varying the shot pattern can mean changes in product size throughout the operation. Smaller shot rock, resulting in less crushing in the secondary and teritary stages, may mean less improvement throughout crushing. Therefore the mineral quality and/or changes in physical properties of the product may be affected.

Hole detonation-sequencing and blast intensity also must be properly engineered. Size changes resulting from installation to detail can have the same effects as mentioned above. Also, an erratic blast that throws the shot rock over a large area will tend to cause variation in size gradation that is delivered to the primary crusher. Any deviation from previously established shot patterns, sequencing, and intensity should be carefully thought as to the effect on product quality. Geologic variability in the deposit can sometimes affect sizing but more often will cause a change in mineral integrity and physical property.

2.6.2.3 CRUSHING

In stone quarries large material usually is reduced in size by either a jaw or a gyratory crusher. After primary crushing, the resulting aggregate generally will be placed in a large “surge” pile where it can be fed into the secondary operation whenever convenient.

Care must be taken when building up and loading out surge piles, as this step can be a major source of segregation of material going to the secondary plant. Variation at this point may affect both mineral quality and gradation. Care should be taken to thoroughly mix the older material a little time with fresh product to make the surge as uniform as possible as it is being pushed into the tunnel. Secondary and tertiary crushing, if necessary, are the final steps in reducing the material to a desired product size.

2.6.2.4 SCREENING

The best technique for gradation control is screening. Screening is a technique used to control both quality and gradation of the aggregate product. If deleterious material still exists at undesirable levels after crushing and can be identified as being predominantly in one size range that is not needed for product size, it may be screened out.

Washing for example, may be necessary to clean a concrete aggregate. Frequent checking of gradation should be a standard operating procedure. Sometimes screening variation is too great even under the most favourable of conditions. The most common reason for high screening variability is the tendency to push too much material over a screen. The only way to maintain a bed of material thin enough for optimum efficiency is to provide enough screening to allow the desired rate of production.

For well-graded products, gradation control may not be accomplished without separating the material into fractions. Frequent sampling, testing and control charting are necessary for monitoring, because aggregates gradation is subject to so many variables.

2.6.2.5 HANDLING IN AGGREGATE PRODUCTION

SEGREGATION

Controlling the production process should be given first priority when beginning on the road to quality. It is here that all the inputs are measured, evaluated, and controlled so that product conformity and uniformity can be predicted. It is often felt that when a uniform product appears on the last belt jobs are finished, but usually it is far from true. Whenever one rock is placed upon another segregation can destroy the uniformity that the producer so carefully built into the product.

Actually, segregation begins on the belt where fines vibrate to the bottom and coarse aggregate remains on the top as the material bounces across the idlers. At the end of the belt, if left undeflected, the coarse particles are thrown out and away. Fine particles, on the other hand, tend to drop down or if wet will even follow back underneath the conveyor.

STOCKPILING

Whenever there is a difference in the process between supply and demand, a stockpile is required. With in the process, if the production of a particular product is not balanced exactly by the demand from a downstream operation then a stockpile must be inserted into the process. Segregation is probably the nemesis of stockpiling and handling, but certainly other problems such as degradation and contamination can adversely affect product quality. Every possible precaution should be taken to protect product quality from the point of manufacture to the point where it leaves the producer's control.

Since most stockpiling problems are created because of inconsistent management, it is very important for the producer to write standard operating procedures on building stockpiles for each product and to educate all those involved in their responsibilities in the procedure.

DEGRADATION

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 retrival 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.

CONTAMINATION

Contamination is usually the result of carelessness and poor house keeping. In order to save space, stockpiles of different products are placed close together and as they grow in size they grow together. Equipments also can track dirt or other foreign matter into the product pile area. And old piles are subject to wind –blown fines over time and should be checked for this before shipping.

2.6.2.6 RETRIVAL

Retrieving material properly from a stockpile is just as important as building the stockpile properly. In retrieving material as well as in building stockpiles a good measure of common sense is necessary. All the effort in creating a consistent product is for naught if care and good practice is not used to keep the product unaltered and consistent up to the point where it leaves the producer's control.

After final preparation of the products, they are stored prior to dispatch in bins, silos or stockpiles. Often storage is combined with a system so that different size fractions can be blended as they are withdrawn from the storage unit to constitute special production requirements.

2.6.2.7 Precautions in Handling and storing Coarse Aggregates

When handling and storing concrete aggregate. The following four points are important[7]:

1. Minimum segregation. Avoid high, cone-shaped stockpiles.
2. Don't allow stockpile equipment on the aggregate stockpile because the concrete aggregate may break down, the gradation may change and/or foreign particles may be introduced.
3. Separate the stockpile from other materials to avoid contamination and to maintain the integrity and gradation of the concrete aggregate.
4. Watch out for extreme exposure to the weather. Be sure to mist during extreme heat. Cover during freezing and protect from high wind.

2.7 STANDARDIZATION IN AGGREGATE PRODUCTION

2.7.1 GENERAL

Standardization is defined as a model or general agreement of a rule established by authority, consensus, or custom, created and used by various levels of interest. The setting of the standard depends on the effect the dimension variation has on the performance of the product [27].

Standardization is required not only for ensuring procurement of the right quality of incoming material, but also for cost reduction. The aim of standardization should be to have uniform standards for similar items, and the standard evolved should take cognizance of the indigenous availability of materials to the maximum extent possible [27].

2.7.2 BENEFITS OF STANDARDIZATION

The important general benefits are as follows:

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

By using national standards, it is easier to locate sources of supplies. The importance of standardization in the construction industry especially for construction materials can not be overemphasized. Industry has become increasingly interested in assessing its economic efficiency, and thus is more interested in the role of standardization. Systematic and reliable results can be attained on a common basis [27].

2.8 CONCRETE AGGREGATE PRODUCTION AND ITS ENVIRONMENTAL IMPACTS

The aggregate industry is presently facing a growing, public awareness in relation to the environmental profile of its activities. 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 neighbourhood 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 a high energy consumption needed per. ton aggregate produced,

These questions in the relation between the aggregate industry and its surrounding society will by far be determinant for the industry's survival potential. In the future, only those companies and branches who can earn their public acceptance from an active use of environmental parameters in their planning and execution of own activities, will survive.

The real challenge here is to merge the environmental issues with the industrial ones; to create industrial plants, which are at the same time environmentally friendly and economically profitable, which integrate quarrying and industrial production, and finally – for which there exist plans for restoration and area use after quarrying period is completed.

2.8.1 IMPACTS OF QUARRY SITES ON THE ENVIRONMENT

Quarries are opened for production of construction material such as selected materials for roads construction, dimension stones for buildings, gravel, aggregates, ceramic and cement raw materials, etc [18].

The following are impacts on the environment due to aggregate production processes.

- Ponds developed in a quarry can serve as breeding ground for water born disease and mosquitoes,
- Children who swim in quarry ponds could draw down and die and can be a threat to animals,

- The vertical cliffs can cause death to animals and human live,
- Land slide and land fall,
- Production of dust,
- Overburden disposal accumulation,
- Affecting farm land or cause land use change,

2.8.2 Mitigation

- Restoration of the completed overburden disposal areas,
- Abandoned qurries should be cultivated and seeded and trees planted,
- Adopt the safest quarry opening method,
- Eliminate hazardous high walls
- Shooting down the high walls
- Cover by soil and re-vegetation
- Establish appropriate quarry drainage system,
- Rehabilitate quarries and refill irregular and level surfaces around quarry sites,

Mining designers must consider the effects of mine on its surroundings. Engineering alternatives have to be judged according to their environmental influence. After a plan is adopted, the effects on the environment should be monitored. Construction materials producers and communities should as a minimum recognize environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management systems.

2.9 Summary

Concrete is a composite product of different ingredient materials. Ensuring the availability and supply of suitable and acceptable ingredients is one of the important tasks towards the production of concrete which satisfies standard requirements. However, since most of the ingredients of concrete are naturally available and are used directly for concrete production it is so important to give due consideration for their production process and be aware of the influence that the different properties of the ingredients have on the properties concrete.

For the aggregate producer, the concrete aggregates are end products, while, for the concrete manufacturer or for the contractor, the aggregates are raw materials to be used for mix designs and successful concrete production. In order to optimize the aggregate-concrete chain, one has to know the aggregate quality characteristics that dominate different concrete properties.

Securing the suitable type of aggregate for concrete production starts from selecting a suitable source that can be used for production of aggregates that satisfy standard requirements. Then follows the production process of these aggregates. Finally transporting the product to the place where, the different ingredients are mixed and concrete is produced, becomes the last part of the process.

Of the different ingredients of concrete, water is one of them and proper test and care should be given before it is used for concrete production. Though, water suitable for drinking or tap water is suitable for concrete production it is also possible to test and use water from other sources.

Cement is also one of the important constituents of concrete and takes the lion share of the total cost of concrete in usual cases. The properties of cement and the amount used in a concrete mix have big influence in the final product, concrete. Of the different types of cements known world wide, OPC and PPC are produced and used in Ethiopia. The quality of the cements produced in Ethiopia is also acceptable when compared to standard requirements. However, there is a big demand of cement that attributes to the huge infrastructure development in the country.

Generally, two types of aggregates are used for concrete production in Ethiopia; coarse aggregates and fine aggregates. Crushed rock aggregate is used as coarse aggregate and river sand is used in most cases as fine aggregate. Since aggregates are directly, without their chemical composition being altered through the production process, used for concrete production it is important to take proper care while processing and handling them. In addition, it is important for the concrete producer to be aware of the influence of the properties of aggregates on concrete.

The physical properties like specific gravity, porosity, thermal, and the chemical properties of aggregates are attributed to the parent rock. However, the shape, surface texture density, porosity, of natural aggregates and shape and surface texture in artificial aggregates are attributed to the mode of production. It is, therefore, very important to give due attention to the source and mode of production of concrete aggregates.

Since igneous rocks are normally hard, tough and dense most of the concrete aggregates are derived of igneous origin. Depending on their weight aggregates can be classified as light, normal and heavy weight aggregates. Light weight aggregates are abundantly found in Ethiopia especially in areas along the Rift Valley. Researches carried out in the Ethiopian light weight aggregates have shown that the Ethiopian aggregates can be used for structural purposes in combination with normal weight aggregates.

As regard to aggregate sources, aggregates which are naturally available are used for concrete production both for coarse and fine aggregates in Ethiopia. In addition, majority of aggregate sources in Addis Ababa are located around rivers within the city with the exceptions of sources of scoria.

Researches carried out in local aggregates in Ethiopia have shown that it is possible to produce high strength concrete using the locally available basalt stone. However, this result was obtained by proper selection of aggregates, limiting the maximum size of aggregates, washing and using higher quality of cement in combination with limiting the w/c ratio. In addition, researches carried out in different parts of Ethiopia indicated that rocks that are suitable, even some times extraordinarily good, for production of suitable concrete aggregate are available in different parts of the country.

Of the different properties of aggregate specific gravity, unit weights, voids, surface moisture, porosity and absorption, gradation, maximum sizes are those which influence the property of the concrete significantly. In addition, physical properties which include shape, texture, strength and modulus of elasticity are also important parameters that affect the final product, the concrete. In addition, aggregate particle shape and texture have big influence in the property of concrete. Crushed and angular aggregates are good for strong concrete production but they require more water for workability than gravel and smooth surfaced aggregates.

Furthermore, it is now recognized that for many conditions, the most important property of concrete is its durability. There are many aspects of concrete durability, and practically all are influenced by the properties of the aggregate. These include alkali-aggregate reaction which in turn is controlled by selection of non- reactive aggregates, use of low alkali cement, use of corrective admixtures such as pozzolanas and controlling the void space in concrete.

The other important property of aggregates with regard to durability is soundness. According to all the researches indicated in this chapter, the soundness values of all the rock samples considered in different parts of Ethiopia satisfies requirements set by standards. This is an indication that the rocks in Ethiopia are suitable potential sources for production of concrete aggregates.

With the same token deleterious substances can also attribute to the durability of concrete. Unless concrete aggregates are free from impurities and deleterious substances the durability of the concrete is in question. This is the very reason why aggregates should be washed before they are used for concrete production.

Other property of concern is the thermal property of aggregates which is expressed by coefficient of expansion, specific heat and thermal conductivity. In dealing with the fire resistance of concrete the study of coefficient of thermal expansion of aggregate is also important. A research has shown that the linear coefficient of thermal expansion of concrete increases as the ratio of cement to sand decreases.

As discussed above production process of aggregates have significant effect on the property of the aggregates which also affect the properties of the final product the concrete. Controlling the production process should be given first priority when beginning on the road to quality.

Unlike coarse aggregate where various types of crushers can be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing by a technique called exclusion. Since sand is usually directly used without its physical property being altered, except washing and screening in some occasions, it is important to maintain the consistency and uniformity of its supply.

Coarse aggregates can be gravel or crushed rocks. Due attention is required especially in the production of coarse aggregates by crushing rocks. The production process basically involves stripping, drilling, blasting, crushing and screening. Frequent sampling, testing and control charting are necessary for monitoring, because aggregates gradation is subject to so many variables. In addition to the production process, care should be taken in handling the aggregates especially while stockpiling and retrieving to avoid segregation, degradation and contamination.

Once the aggregates are produced the following step is transporting and delivering it to concrete mixing places. The purpose of careful handling and control, in proper sequence, is to produce satisfactorily a selected batch assembly for the continuous production of homogeneous concrete. Therefore, to ensure the proper handling of aggregates, the separate delivery, storage and batching of coarse and fine aggregate is essential.

Unless care is taken in the handling and storing of aggregates, there is a marked tendency for segregation of the fine and coarse particles to occur. In general, there is less danger of segregation in coarse aggregates if they are screened into two or more size ranges and handled separately.

One important aspect in the process of handling of concrete making materials is storage. At all stages up to the time of use, cement must be kept dry so as to prevent or minimize deterioration from the effects of moisture, atmospheric humidity and carbonation. In addition, 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.

Since aggregates and cement are non renewable resources there is no means to reuse them unless they are recycled which of course is a technology that Ethiopia can't afford to have currently. Therefore, in construction projects and ready- mixed concrete production plants, care should be taken to avoid wastage of concrete making materials as much as possible.

One important aspect in handling of concrete making materials is the method used in batching for concrete mix. There is no problem normally in batching cements since they are usually delivered in bags in Ethiopia. However, fine and coarse aggregates can be batched gravimetrically, manually or volumetrically. As it is well known, aggregates are normally batched volumetrically in construction projects in Ethiopia. Volumetric batching might result in unnecessary concrete mix unless the moisture content and density of the aggregates being measured is known and proper care and adjustment is taken.

Testing concrete making materials helps to ensure good quality material. However, equally important is the effort that is needed to acquire a truly representative quantity of the consignment being sampled and of sufficient quantity for the tests required. In addition, where practicable, samples to be tested for quality should be obtained from the finished product.

One key aspect towards ensuring the quality of aggregate which is suitable for concrete production is standardization. Where there is standardization and proper control manufacturers and producers will be expected to produce consistent and uniform product and it would also be easy for the consumer to get a material of his interest.

The environmental impact that aggregate production plants have is drawing the attention of the public in the recent years. In addition, the relation between the aggregate industry and its surrounding society will be determinant for the industry's survival potential. Some of the environmental impacts of aggregate production are: formation of ponds, formation of high vertical cliffs, dust production, affecting land cause and land change, sound and vibration on the neighbouring inhabitants.

Construction materials producers and communities should as a minimum recognize environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management system. This is important to avoid unnecessary investment and also for an optimized utilization of natural resources.

3. AGGREGATE PRODUCTION IN THE ETHIOPIAN CONSTRUCTION INDUSTRY

3.1 GENERAL

Aggregates are important construction materials, both for new constructions and maintenance works. Aggregates are valuable natural resource and it is our obligation to use these materials sensibly. To use aggregates for the intended purpose due attention should be given to the production process employed to get aggregate of the right quality.

The vast majority of materials used in the mineral aggregate industry are obtained from surface-mined stone quarries or from sand and gravel pits. How materials are extracted influences their quality. Good understanding of the basic material properties, usage possibilities and quality are significant for sensible use of aggregate resources.

Knowledge of material properties may aid in the selection of aggregates to ensure optimum use of the resource. For instance, high quality (and valuable) aggregate may be used for the more expensive constructions whereas aggregates with lower quality may be selected for massive fills where quality demands are not as such strict. In addition, unnecessary damages to the nature may be prevented, optimum exploitation of the resource may be achieved and environmental effects may be better estimated. Further, it is important for responsible parties to be up to date with locations and details of existing and potential quarries.

The geology of material suitable for aggregates is highly variable and sources are widespread. However, not all rocks make good aggregates. Good aggregates must be hard and tough and shouldn't not break down or disintegrate easily. In addition, the site for a quarry will depend on the suitability of the material, proximity to populated areas, transport costs, existing and planned land use, the impact on the environment and the rehabilitation of the site after quarrying operations have ended. Finally, possible sites are prospected thoroughly and core samples are taken to test for suitable aggregate products [47].

Useful resources of aggregates are widespread, but in some places they are of small volume and are replenished slowly or are not currently available at all. The prodigious demands of modern industrial and residential construction frequently overtax the supply. In Japan, for example, the sand and gravel has been entirely removed from many river channels and supplies must be imported from Taiwan. In different countries there are important regional differences in the availability and quality of sand and gravel and in the types of sources from which these materials can be obtained [29].

The location and accessibility of sand and gravel supplies determine the feasibility and cost of transport to the site of consumption. Thus, many deposits may be unused because they lie in places, too distant from construction sites or roads. In some cases a trade-off may be necessary between the high cost of transport from distant sources and the environmental disturbance that may result from gravel operations at more accessible locations. Many of these sources will soon be exhausted, and others have already been rendered inaccessible by past and present urbanization [29].

The availability and supply of coarse aggregate from the currently identified and potential sources is influenced by a number of factors, such as cost of transport, competing land uses, and the environmental impacts of extraction and transport. Therefore, it is imperative that a strategy for sourcing and transporting large quantities of aggregate from outside the region be adopted for future management of identified and potential concrete aggregate resources[29].

3.2 AGGREGATE PRODUCTION IN THE ETHIOPIAN CONSTRUCTION INDUSTRY

It is a known fact that concrete making aggregates are the major building materials in Ethiopia. Most structures, including domestic houses, roads, bridges and hydropower dams, which are necessity for the development of the country are built with these materials. Huge amount of resource is invested in these structures and infrastructure. As a consequence, knowledge of the properties of the aggregates, sustainability and quality of deposits are required in order to obtain a rational use of these materials. Since it was not possible to get a reliable data about the total yearly production of aggregates in Ethiopia mainly the data collected from Addis Ababa is used in this research.

3.2.1 CONSTRUCTION MATERIALS PRODUCTION IN ADDIS ABABA

The city Addis Ababa City is growing from time to time very rapidly. Its area which is 54,000 Ha is being covered by buildings, houses, roads, bridges etc. This shows the high demand of construction materials, which includes rocks for the production of concrete making aggregates. Except ten of the existing aggregate producing firms in the city the rest are not well organized in manpower, in machinery and in finance. respectively. In addition, the potential of the area they are using is very low that the production capacity of these firms is correspondingly very small.

Due to the above mentioned facts the existing big supply-demand gap imposes negative influence to the existing construction activity in the city. Yearly production and number and location of licensed quarries in Addis Ababa are shown in Table 3.1 and Table 3.2 [19].

Table 3.1 Yearly Production and Sale of Coarse Aggregate Produced by Aggregate Producers Registered in Addis Ababa from 1995 - 2000 [19]

Budget Year	Total Sale (Birr)	Total Production (m^3)
1995/96	9,763,574.67	443,798.85
1996/97	11,897,063.33	169,958.05
1997/98	32,689,733.50	384,585.1
1998/99	23,917,761.55	281,385.43
1999/2000	15,241,032.34	179,119.62

Table 3.2 Number and Locations of Licensed Quarries in Addis Ababa (Source : Addis Ababa Environmental Protection Authority 2005)

Sub City	Construction Minerals			
	Basalt	**Ignimbrite**	**Selected Material**	**Scoria**
Bole	80	125	11	-
Nefas Silk Lafto	-	100	4	-
Akaki-kaliti	65	15		25
Yeka	6	10	3	-
Kolfe Keranio	1	-	-	-
Total	**152**	**250**	**25**	**25**

In general, changes in the level of demand for rock materials occur because of previous or present changes in the characteristics of the overall country's economy. Thus, it would be expected that a relationship exists between trends in the level of rock production and various indicators of the general economic activity. Per capita consumption rates vary greatly, depending upon the degree of urban maturity reached within a region. High per capita consumption rates are generally characteristic of regions where the overall population density is relatively low and the rate of urban development is high.

For comparison the total aggregate production trend in the German construction industry is shown in Table 3.3. There was recession in the construction industry in Germany the last ten years due to the decrease in growth of the total economy. This is the reason why there is a decrease in the production of aggregates in the years from 1995 onwards. The reason that it was not possible to get a reliable data concerning total aggregate production in Ethiopia, made the comparison in quantity of the aggregate production in German with the production in Ethiopia difficult.

Table 3.3 Trend of Aggregate Production in the Germany Construction Industry

Year[11]	Produced in Mill. t	Sold in Mill. Euro	Sold in Mill. Birr[12]
1950	23.3	31	330.89
1960	96.8	176	1878.61
1970	206.4	463	4942.02
1980	190.3	644	6873.99
1990	159.1	749	7994.75
1991	163.0	822	8773.95
1993	213.4	1188	12680.59
1994	244.1	1357	14484.48
1995	193.7	1107	11816.01
1996	182.4	1021	10898.05
1997	176.9	980	10460.42
1998	169.0	933	9958.75
1999	178.3	987	10535.14
2000	164.6	913	9745.27
2001	148.3	821	8763.27

As it was mentioned above, Addis Ababa is expanding in all directions. Such rapid expansion needs engineering geological information for planning, design and assessment of construction materials. Construction earth materials including basalt, ignimbrite, red-ash and brick soil are available and found distributed in all corridors except the northern part of Addis Ababa. Environmental, social and economic impacts are however experienced during mining activities with regard to different quarry sites [20]. Potential Construction Raw Materials in Addis Ababa and its Surrounding is shown in Figure 3.1.

[11] The data before 1993 is only for the former Western Germany and the data from 1993 on wards is the total aggregate produced by Germany after the unification.

[12] 1€ = 10.6739 Ethiopian Birr (Exchange rate on July 2005, Interbank Rate)

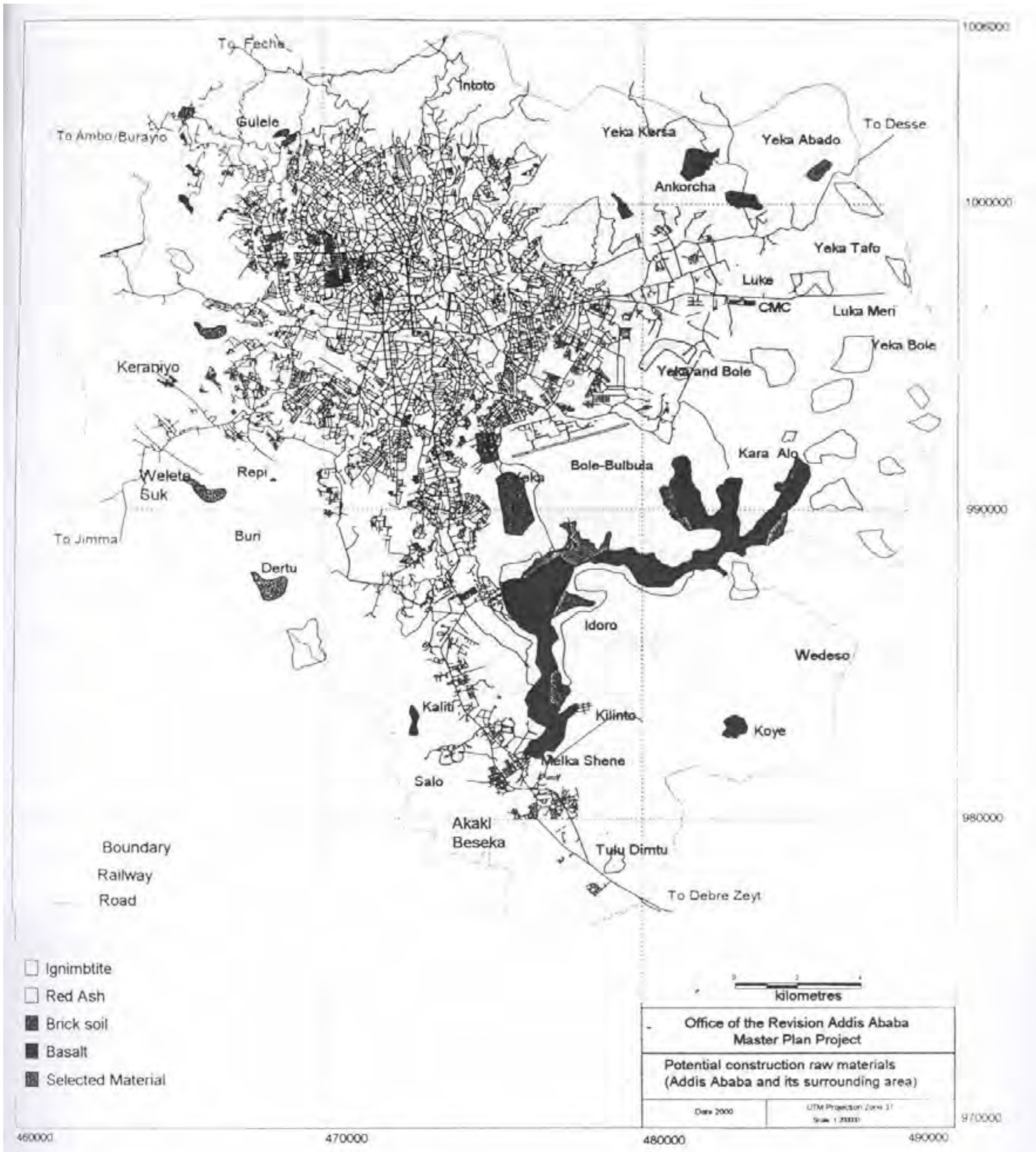


Fig 3.1 Potential Construction Raw Materials in Addis Ababa and its Surrounding [21]

3.2.2 AGGREGATE PRODUCTION METHODS IN THE ETHIOPIAN CONSTRUCTION INDUSTRY

3.2.2.1 FINE AGGREGATE

Natural fine aggregate or sand is dredged from river beds in most parts of Ethiopia. Finely crushed aggregate is also used in some parts of the country where natural sand is not available. In most parts of the country, though the quality varies significantly one from the other, fine aggregate is available abundantly at least for the present.

Sources of Fine Aggrgates

As most of the aggregate used in Ethiopia is from river beds mostly fine aggregate is not produced in wet seasons. One reason for this is that since the river over flows in that period it would not be possible for sand producers to get into the river bed and collect the sand. The other reason is that most sand production sites are not accessible by vehicles in this period.

Production Methods

Sand production sites are not mechanized. The production is done by local people of the area using traditional method of collecting the sand from the river bed by donkey (carrying capacity of not greater than 70 kg or 0.05 m^3 per trip), depositing it to a place where vehicles can get in. Fig. 3.2 and Fig 3.3 show the primitive but the usual way of producing sand in Koka 90 kms south east of Addis Ababa. Fine aggregate demands of Addis Ababa is met by sand produced in this same manner. Finally, the collected sand is loaded manually on dump trucks and is then transported to the actual site or concrete production plants and is directly used for actual concrete production or related works. Some part of it might be sent to construction material suppliers and is sold out for users who need the sand in varying amount.

The production method of sand in Ethiopia is so primitive that the sand produced in this manner is exposed to the following situations.

1. Since it is collected in a primitive manner by human labour using small hand tools, it is susceptible to a greater degree of non-uniformity; this non uniformity can be expressed by its gradation.
2. Since it is transported by donkey and collected somewhere in an unprepared ground, it is susceptible to contamination by deleterious substances.
3. There is no room for quality check up.
4. There is no room for modern production of standardized product.
5. Most sand producers are local farmers who have no detail technical knowledge about the material they produce. The only knowledge they have doesn't go far from what they are informally heard from their product customers.
6. The local producers are quite numerous in a single local area that it is difficult to get consistent supply from a specific area.
7. Since the sand itself is naturally available material it is quite difficult to get a consistent supply from same location even in hours interval.
8. There is wastage of material in the process.

Fig 3.2 Sand being collected from river bed manually around Koka.

Fig 3.3 Sand being collected by human labor and being loaded on back of a donkey around Koka.

In the Germany construction industry fine aggregate is produced from naturally available river sand and from crushed rocks. As far as the production process is concerned the fine aggregate supplied for concrete producers is washed and checked for proper gradation. The produced fine aggregate is normally incompliance with the standard of the country (DIN). From interviews made in ready mix concrete production plant personnel and experienced civil engineers in Germany it has been realized that the aggregate supplied for concrete production is in most cases is up to the standard.

3.2.2.2 COARSE AGGREGATES

Coarse aggregate is produced in Ethiopia using aggregate crushers and by crushing manually using human labor and small hand tools. Especially, in rural areas and in construction sites where the coarse aggregate demand is low manual crushing is normally experienced. In addition, the crusher plants vary in size and production quality.

In this research, visits were made to different large and small scaled coarse aggregate production plants in and around Addis Ababa. The summary of the general production technique followed by the plants is presented below.

PRODUCTION METHODS

1. Crushing by Human labor and Hand tools

Procedure

1. Boulders are collected
2. Very big ones are broken down, using sludge hammer and wedge, in to smaller units.
3. Very strong boulders are broken down after they are burnt for hours with high temperature using worn out vehicle tires.
4. The broken relatively smaller boulders are then further broken down by hand /human labor/ using sledge hammers (1 – 3Kg.). Figure 3.4 shows boulders being further broken down into smaller pieces by human labor.

The following problems are associated with this method of production:

1. Production is by human labor which results high degree of non uniform and inconsistent product. Especially, the gradation and shape of the aggregate produced will certainly be poor.
2. It is not up to the standard
3. It has environmental impacts
   - CO_2 from the smoke,
   - risky working environment to the workers due to flying stones,
4. Has problems associated with the production process
   - production is too little,

– not convenient to quality control,

– not feasible in places where relatively smaller boulders are not readily available,

– difficult to rely on the quality and quantity produced by this process

Fig 3.4 Boulders for coarse aggregate preparation being crushed by human labor.

2. Low Scale Mechanized Crushing

1. Boulders are collected
2. Very big ones are broken down, using sludge hammer and wedge, in to smaller units.
3. Very strong boulders are broken down after they are burnt for hours with high temperature using worn our vehicle tyres.
4. The relatively smaller boulders are fed in to the crusher and are crushed into smaller sizes. Figure 3.5 shows a small scale mechanized crushing plant.

Fig 3.5 Low scaled coarse aggregate crushing plant around Nazreth.

Problems associated with this method of production

1. Production is relatively low.
2. The row crushed stone is prepared by human labor which results high degree of non uniformity and inconsistency of the product. Especially the gradation and shape of the aggregate produced is quite poor. Flaky aggregate particles result from this mode of aggregate production. In addition, it is not feasible in places where relatively smaller boulders are not readily available.
3. Quality- The boulders they usually use for production are so weak that the resulting product becomes of low quality. In addition, it is not convenient to quality control.
4. It is not up to the standard
5. It has environmental impacts there is emission of CO_2 from the smoke and the working environment is risky to the workers due to flying stones.
6. Production is relatively small and it is not reliable both in respets of quality and quantity.

3. Medium to Large Scaled Crushing Plants

These types of crushing plants use open pit quarrying method of aggregate production. They have the following characteristics.

1. Have big plots of land and are usually established after some geological investigation is carries out in the area especially in the availability, potential and to some extent to the quality of base rock suitable for coarse aggregate production.
2. At the beginning of the production process, the over burden is removed and the area is made ready for drilling before the actual process of blasting is started. This step involves stripping the overburden and exposing the bedrock for blasting. Here selected materials production is carried out in the mean time.
3. Usually boulders are produced from the existing big alluvial stratum/bed rock by a process of blasting.
4. Blasting is usually carried out using explosives. In order to carry out blasting holes for explosives are drilled using Wagon Drilling Rigs and Manual Perforators at a certain calculated distance.
5. Dynamites are inserted which are connected with detonating cord relay and safety fuses attached at the end of the explosion.
6. Blasting is then carried out by explosives, ammonia nitrate or gelatin 30.
7. The resulting rock is again blasted if it happens that it is too big for the continuing production process and this process is called secondary blasting. After the blasting is carried out, the blasted rock is collected using excavators and is loaded on dump trucks using loaders preferably chain loaders.
8. The resulting crushed rock is then further crushed using Dozers. The crushed rock is then sent to the crushing site by a dump truck and stock piled.
9. The stock piled crushed rock is then fed to the crusher and will further be crushed in to rather different smaller sizes.
10. Using separators, which are usually three or more, the crushed rock is stock piled and becomes ready for use. The usual range of production capacities of crusher plants in Ethiopia are:

Jaw Crushers	95 m^3/hr
Cone Crushers	71 m^3/hr

11. Finally it is loaded on dump trucks and is then transported to the actual construction sites. Figure 3.6 shows one of the biggest aggregate production plants in Addis Ababa.

Fig 3.6 Large scaled coarse aggregate production plant (Blue Nile -around Kaliti)

Comparison with other methods of production

1. The production system is controlled
2. The gradation of the resulting aggregate is relatively good and convenient for quality control
3. Carried out by a relatively trained personnel
4. It has a reliable supply
5. High production capacity per day
6. Has high environmental impact
7. Convenient for production of standardized product

In Germany there are three methods of aggregate production. The first one is to collect and treat naturally available gravel and to use it directly for concrete production. The other two methods are to crush naturally available rock into different sizes and to produce aggregates artificially respectively. In the visit made to an aggregate production plant in Germany it has been observed that the aggregate producer takes all the necessary care to produce an aggregate of acceptable quality. In blasting the bed rock they use bench method which helps to the efficient utilization of the available natural resources.

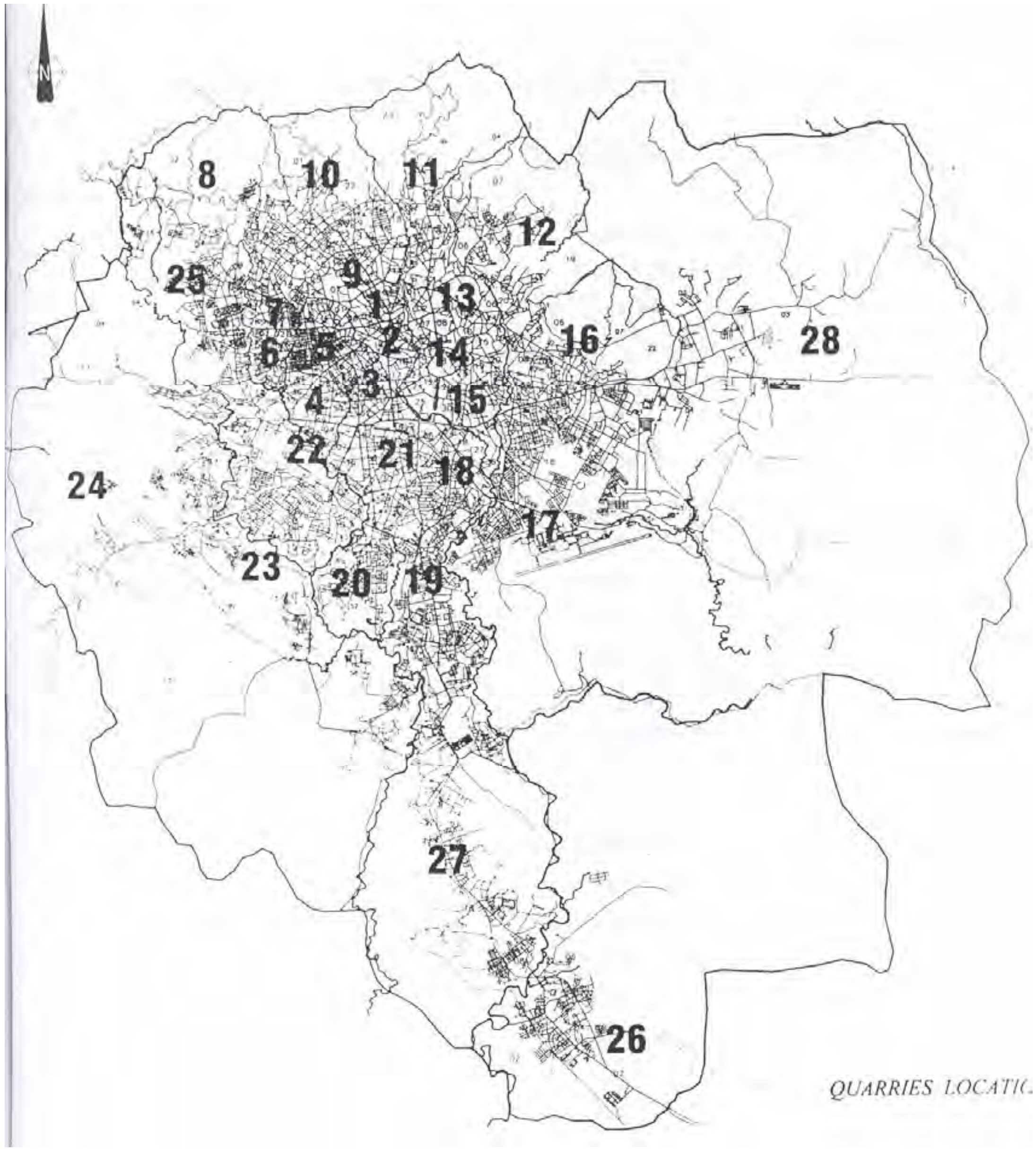
3.3 ENVIRONMENTAL IMPACTS OF AGGREGATE PRODUCTION PLANTS IN THE ETHIOPIAN CONSTRUCTION INDUSTRY

Quarries are opened for production of construction material such as selected materials for roads construction, dimension stones for buildings, gravel for aggregates, and ceramic and cement raw materials, etc. However, quarry operations have impact on the surrounging environment. Especially, the environmental impacts of aggregate production plants which are located in and around cities can not be underestimated. Aggregate production plants in and around Addis Ababa are good examples. The discussion made in this section concentrates on the situation of aggregate production in Addis Ababa.

One of the environmental impacts that aggregate production plants have on the environment and on the inhabitants dwelling nearby is the dust that results while crushing the aggregate. Fig 3.7 shows dust produced by a process of aggregate production in one of the biggest aggregate production plants in Addis Ababa.

Fig 3.7 Dust produced by a process of coarse aggregate production (Blue Nile)

Most of the materials used in the building of cities have natural origin. In obtaining these materials there are a number of active and abandoned quarries which change the natural topography in Addis Ababa. Abandoned quarries are left open and some of them becoming ponds, or domestic waste is dumped to them which become favorable place for flies and other insects breeding. Unless old quarries are filled and planted with trees it would be difficult to avoid their hazardous consequences [20]. Fig. 3.8 shows location and number of abandoned quarry sites in Addis Ababa.



Scale 1:2000

Fig 3.8 Locations of abandoned quarries in Addis Ababa <u>Source:</u> Mines and Energy Department, 2000. (Addis Ababa Works and Urban Development Bureau)

It is to be recalled that one big aggregate production plat which is located at a populated area and surrounded by a hospital and a school in Addis Ababa was abandoned for the reasons of environmental protection and public safety. This quarry site has been operational since 1966 and used to produce an aggregate of best quality. This was evident from the test results that were carried out on samples taken from this quarry site. In the plant there is a cliff that has a height of more than 30 meters and it is possible to observe the houses located on top it. Figure 3.9 and Figure 3.10 show the cliff resulted from the production of coarse aggregate in Addis Ababa.

Fig 3.9 Impact of coarse aggregate production on the environment (The Addis Ababa City Administration Construction Materials Production Plant)

Fig 3.10 Coarse aggregate crushing plants have effect on nearby inhabitants, schools, hospitals, factories etc. especially when they are located with in cities

It has been observed from a visit made in an aggregate production plant that the environmental impact of aggregate production plants in Germany is quite minimum when compared to the situation in Ethiopia. In general the following points were observed:

1. Aggregate production plants in Germany are relatively far from nearby inhabitants,
2. Plants are surrounded by vegetation that the impact of dust pollution is minimized,
3. Measurements are always taken to investigate the impact that the operation in the plant has on the surrounding environment and inhabitants. For instance measurements of the extent of vibration to a certain distance from the plant are carried out whenever there is blasting operation in the plant.
4. Produced material are checked for their compliance (it is also rechecked by the concrete producer later on),
5. Plants are highly mechanized,
6. Operations of the plants are carried out by highly experienced personals.

3.4 CONSTRUCTION MATERIALS HANDLING IN CONSTRUCTION PROJECTS

Observations were made and construction managers and project engineers were interviewed to assess how concrete making materials are handled in construction projects in Ethiopia. From the observations made the following conclusions were drawn.

1. Construction materials are stock piled with out given due consideration;
2. Almost all concrete used by the contractors in Ethiopia is produced on site and Ready-mixed concrete production is not normally used except in few construction projects;
3. The practice of quality control is too loose. In some cases is not even required by the consultants and it is not adequately stated in contract documents
4. Due to production problems the aggregates delivered to the construction site:
    - are not to the required quality (under quality)
    - the supply is not consistent
    - there is high degree of non-uniformity of supplies
5. Some contractors take the following measures in order to produce concrete that satisfies requirements and for benefication of aggregates:
    - Washing the aggregates on site,
    - Making conservative mix design and
    - Using cement that hardens fast in place of the specified cement in contract documents.

To assess the situation of handling of concrete making materials in the German construction industry, on site observations and interviews were made. Unlike the situation in Ethiopia on site concrete production is too rare in Germany. When precast concrete is not considered ready mixed concrete production constitutes 87% of the total concrete produced in Germany. In addition, ready mix concrete production consumes 47.10 % of the total cement produced in Germany.

3.5 COARSE AGGREGATE DEMAND IN ADDIS ABABA

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

Detail studies done so far have shown that the ever increasing demand for quarry output, the continuous increase in the budget allocated to the construction sector and the new economic policy etc. are providing more favorable condition especially for the quarry operation sector [23].

Gravel is needed in Addis Ababa for different constructions including roads and buildings. However, obtaining accurate statistical information concerning the demand of the city is very difficult if not impossible. Hence, attempt was done to estimate the demand of gravel of Addis Ababa in 2003 and it was found to be 829,583 m^3. The annual growth rate of the demand was taken as 5% and the demand for 5 years is projected. In addition, the annual production capacity of the then existing quarries was calculated and the supply and demand gap was calculated [23].

There were about 50 private and public organizations which were licensed by the Mining Department to produce gravel in 2003. The quantity of gravel produced by these units was estimated to be 399,840 m^3 in 2003. A 4% annual growth was considered and their supply was calculated. The supply and demand gap determined form this study is shown in Table 3.4. Accordingly, as it is shown in the table the supply demand gap of coarse aggreaget in Addis Ababa is more than 50 %. From this figure it is clear that shortage in supply of the aggregate is imposing a negative influence on the construction industry activities in the city. However, this figure requires further refinement and studies should be conducted in depth to determine the actual demand and supply condition of concrete aggregates in Addis Ababa in particular and in Ethiopia in general [23].

Table 3.4 Projected Supply and Demand Condition of Addis Ababa [23].

Year	Demand (m^3)	Supply (m^3)	Excess Demand (m^3)	Percentage Gap
2003	829,583	399,840	429,743	51.80
2004	871,062	415,834	455,228	52.26
2005	914,615	432,467	482,148	52.72
2006	960,346	449,766	510,580	53.17
2007	1,008,363	467,757	540,606	53.61

There are a lot of different potentially dependable sites in Addis Ababa and its surrounding metropolitan area which are rich in basalt, ignimbrite, selected material, scoria and brick soil among others. There is however not so much follow-up, evaluation and monitoring of quarrying activities by the legally empowered and concerned institution i.e. the Mining and Energy Department [47].

The exploitation and extraction of these construction material resources has mostly been undertaken in unplanned and uncontrolled manner. On the other hand, this has created various problems such as environmental, social, economical, poor land use management … etc. Thus, quarry sites are found to be devoid of vegetation cover, hollow and disgusting to sight, dangerous and psychologically unacceptable to residents around them [47]. In Ethiopia in general and in Addis Ababa in particular aggregates for concrete production are available in sufficient quantity, for the present at least. In recent years temporary shortages of materials have indicated the problems that could be caused by more serious shortages. Shortages in other industries can affect supplies to the construction industry as well. Many experts have experienced serious doubts about the long-term availability of our present natural resources, and this must concern everyone in the industry. Research into alternative sources of supply should also be conducted [7].

Unlike the situation in Ethiopia, it has been observed from the visits and interviews made in Germany that there is not as such supply and demand gap of concrete making materials. Concrete producers don't have constraint concerning these resources. It is usually the case for customers to get the material they order on time.

4. RESULTS

To investigate the quality and availability of suitable concrete making aggregates in Ethiopia, test results of coarse aggregate, fine aggregate and rock samples were collected from two prominent Construction Materials Testing Laboratories in Addis Ababa. The collected data consists, test results of 47 fine aggregate, 37 coarse aggregate and 4 rock samples. The test samples were collected from tests carried out b/n 3rd of October 2004 and 14th of May 2005.

4.1 GENERAL

The number and distribution of test sample results used in the research are shown in Table 4.1 and Annex A1.

Table 4.1 Number and distribution in percentage of test sample results from and out of Addis Ababa.

Material	Addis Ababa and Its Surrounding		Different localities Out of Addis Ababa		Location Unknown		Total	
	No.	%	No.	%	No.	%	No.	%
Coarse	22	59.46	11	29.73	4	10.81	37	100
Fine	36	76.60	9	19.15	2	4.25	47	100
Rock Sample	1	25.00	3	75.00	-	-	4	100

4.2 FINE AGGREGATES

The fine aggregate samples were randomly collected from tests carried out between 3rd of December 2004 and 10th of May 2005.

4.2.1 GRADATION OF THE SAMPLES

To see whether the samples satisfy the gradation requirement set by the Ethiopian Standard, gradation charts were prepared and their gradations were checked in light of the given requirement in the Standard. The gradations of the samples were characterized as coarser, finer and other. Coarser samples had a percentage passing value below that stipulated in the standard and finer samples had a percentage passing value above that stipulated in the standard at least in one sieve size. The results of the analysis are summarized in Table 4.2 and Annex C1.

Table 4.2 Distribution in number and percentage of Fine Aggregate Samples with respect to the gradation requirements of the Ethiopian Standard (ES. C. D3. 201).

Condition		Number and percentage of Samples						Total	
		In & around A.A		Out of A.A		Location Unknown			
		No.	%	No.	%	No.	%	No.	%
Not complying	**Coarser**	17	36.96	6	13.04	-	-	23	50.00
	Finer	2	4.35	-	-	1	2.17	3	6.52
	Other[13]	-	-	-	-	-	-	-	-
Complying		17	36.96	2	4.35	1	2.17	20	43.48
	Total	36	78.26	8	17.39	2	4.35	46	100

4.2.2 FINENESS MODULUS

According to the requirement of the Ethiopian standard (ES. C. D3. 201) the fineness modulus shall not be less than 2.0 and more than 3.5 with a tolerance of ± 0.20. The result of the fineness modulus of the fine aggregate samples is summarized in Table 4.3 and Annex B1.

Table 4.3 Distribution in Number and in Percentage of Fineness Modulus of the Collected Fine Aggregate Samples.

Fineness Modulus	Number and Percentage of Taste Samples						Total	
	In & around A.A		Out of A.A		Location Unknown			
	No.	%	No.	%	No.	%	No.	%
Below 2.0	-	-	-	-	-	-	-	-
B/n 2.0 and 3.5	34	73.91	8	13.39	2	4.35	44	95.65
Above 3.5	2	4.35	-	-	-	-	2	4.35
Total	36	78.26	8	13.39	2	4.35	46	100

Fineness Modulus range : **2.10 – 3.74**

Average : **2.96**

4.2.3 ORGANIC IMPURITY

In the Ethiopian Standard nothing is stated concerning the limit of organic contents of fine aggreagtes. However, ASTM (C40 – 79)states that plat number 3 is the maximum value allowed for fine aggregates as far as their organic content is concerned. The organic impurity of the fine aggregate samples is summarized in Table 4.4 and Annex D1.

[13] This is a condition where the requirement is not satisfied in more than two sieve sizes in which at least one is above the upper limit and one below the lower limit.

Table 4.4 Distribution in Number and Percentage of the Organic Impurity of the Fine Aggregate Samples with Respect to Requirement of ASTM.

Plate Number	Number and Percentage of Taste Samples						Total	
	In & around A.A		Out of A.A		Location Unknown			
	No.	%	No.	%	No.	%	No.	%
< = 3.0	35	74.47	8	17.02	2	4.25	45	95.74
Above 3.0	1	2.13	1	2.13	-	-	2	4.26
Total	36	76.60	9	19.15	2	4.25	47	47

Organic Impurity range (Plate Number) : **1 – 4**

Average **: 2.14**

4.2.4 LOOSE UNIT WEIGHT

There is no limit stated in the Ethiopian and other internationally accepted standards concerning unit weights of fine aggregates. However a range where unit weights of good concrete aggregates fall is given in different literature. Literature recommends that good fine aggregate has a unit weight in the range of 1520 – 1680 kg/m^3 [9]. Table 4.5 (Annex E1) shows the number and percentage of the loose unit weight of the fine aggregate samples.

Table 4.5 Distribution in number and percentage of the Loose Unit Weight of the Fine Aggregate Samples.

Loose Unit Weight (kg/m^3)	Number and Percentage of Taste Samples				Total	
	In and around A.A		Out of A.A			
	No.	%	No.	%	No.	%
Below 1520	18	78.26	3	13.04	21	91.30
1520 – 1680	-	-	2	8.70	2	8.70
Above 1680	18	-	-	-	-	-
Total	18	78.26	5	21.74	23	23

Loose Unit Weight range : **756 – 1572 kg/m^3**

Average : **1183.78 kg/ m^3**

4.2.5 COMPACTED UNIT WEIGHT

Similar to the above discussion, there is no limit stated in the Ethiopian and other internationally accepted standards concerning unit weights of fine aggregates. However, a range where unit weights of good concrete aggregates fall is given in literature. Literature indicate that good fine aggregate has a unit weight in the range of 1520 – 1680 kg/m^3 [9]. Table 4.6 (Annex E1) shows the number and percentage of the loose unit weight values of the fine aggregate samples.

Table 4.6 Distribution in number and percentage of the Compacted Unit Weight of the Fine Aggregate Samples.

Compacted Unit weight (kg/m^3)	Number and Percentage of Taste Samples				Total	
	In & around A.A		Out of A.A			
	No.	%	No.	%	No.	%
Below 1520	18	78.26	1	4.35	21	91.30
1520 – 1680	-	-	4	17.39	2	8.70
Above 1680	18	-	-	-	-	-
Total	18	78.26	5	21.74	23	100

Compacted Unit Weight range : **850 – 1667 kg/m^3**

Average : **1311.22 kg/m^3**

4.2.6 SILT AND CLAY CONTENT

The Ethiopian Standard stipulates that the silt and clay contents of a fine aggregate sample should be less than or equal to 3% for concrete subject to abrasion and less than or equal to 5% for all other concrete (ES. C. D3. 201). The silt and clay contents of the fine aggregate samples are shown in Table 4.7 (Annex D1) below.

Table 4.7 Distribution in Number and Percentage of the Silt and Clay Content of the Fine Aggregate Samples.

Silt and Clay Content (%)	Number and distribution of Taste Samples						Total	
	In & around A.A		Out of A.A		Location Unknown			
	No.	%	No.	%	No.	%	No.	%
Below 3%	12	30.77	5	12.82	2	5.13	19	48.72
3 - 5	7	17.95	1	2.56	-	-	8	20.51
Above 5%	12	30.77	-	-	-	-	12	30.77
Total	31	79.49	6	15.38	2	5.13	39	100

Silt and Clay Content range : **0.77 – 12.62 %**

Average : **3.95 %**

4.2.7 SPECIFIC GRAVITY

The Ethiopian Standard requires that the apparent specifc gravity of a normal concrete aggregate lies b/n the range of 2.4 and 3.0 (ES. C. D3. 201). Table 4.8 (Annex F1) shows the summary of distribution of the specific gravities of the fine aggregate samples in number and percentage.

Table 4.8 Specific Gravity of the Fine Aggregate Samples with respect to requirement of the Ethiopian Standard.

Specific Gravity		Number and percentage of Taste Samples				Total	
Type	Range	Around & in A.A		Out of A.A.			
		No.	%	No.	%	No.	%
Bulk	Below 2.40	3	30	-	-	**3**	**30**
	2.40 – 3.0	-	-	7	70	**7**	**70**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**3**	**30**	**7**	**70**	**10**	**100**
Bulk (SSD)	Below 2.40		30	1	10	**4**	**40**
	2.40 – 3.0	3	-	6	60	**6**	**60**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**-**	**30**	**7**	**70**	**10**	**100**
Apparent	Below 2.40	-	-	-	-	**-**	**-**
	2.40 – 3.0	3	30	7	70	**1**	**10**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**3**	**30**	**10**	**100**	**10**	**100**

Bulk Specific Gravity range : **2.20 – 2.64**
Average : **2.42**
Bulk (SSD) Specific Gravity range : **2.30 – 2.67**
Average : **2.49**
Apparent Specific Gravity range : **2.41 – 2.81**
Average : **2.61**

4.2.8 WATER ABSORPTION

There is no requirement concerning water absorption in the Ethiopian Standard. However, ASTM states that the water absorption of good fine aggregate is in the range of 0.2 to 4% (ASTM C127). Table 4.9 (Annex F1) shows the summary of the water absorption of the fine aggregate samples.

Table 4.9 Water Absorption Capacity of the Fine Aggregate Samples with respect to the requirement of ASTM.

Water Absorption (%)	Number and percentage of Taste Samples						Total	
	Around & in A.A		Out of A.A		Location unknown			
	No.	%	No.	%	No.	%	No.	%
Below 0.2	-	-	-	-	-	-	-	-
B/n 0.2 & 4	2	20	6	60	-	-	8	80
Above 4	1	10	1	10	-	-	2	20
Total	3	30	7	70	-	-	10	100

Water Absorption Range : **0.79 – 5.75 %**

Average : **2.89 %**

4.2.9 Clay Lumps Content

Two test samples from out of Addis were tested for clay lumps content and the results obtained were 1.25% for the first sample and Nil for the second sample. The maximum limit set by ASTM for clay lumps content is 3%. This shows that both samples satisfy the ASTM's requirement.

4.2.10 Chloride Content

One sample was tested for chloride content and the result was found to be 4.70 mg/liter which extraordinarily satisfies the maximum limit set by the British Standard which is 600 mg/iltre.

4.2.11 Soundness

Two test samples from out of Addis were tested for soundness by sodium sulphate method and the results were found to be 10.53 and 13.11 percent respectively. However, the maximum loss stated in the ASTM is 10%. This shows that the samples didn't satisfy the requirement. The ES stipulates that fine aggregate, when subjected to five cycles of soundness test, shall not show loss in mass exceeding 10 percent when sodium sulphate solution is used or 15 percent when magnesium sulphate solution is used. Therefore, in both cases the samples don't satisfy the requirements.

4.3 COARSE AGGREGATES

4.3.1 GENERAL

The number and percentage of the coarse aggregate sample results used in the research is shown in Table 4.10 (Annex A2).

Table 4.10 Distribution of Coarse Aggregate Types Used in the Analysis

Nominal Maximum Aggregate Size	Number and percentage of Samples						Total	
	In & around A.A		Out of A.A		Source Unknown			
	No.	%	No.	%	No.	%	No.	%
38 – 5	14	37.84	6	16.22	2	5.40	22	59.46
19 – 5	4	10.81	3	8.10	-	-	7	18.91
13 – 5	3	8.10	1	2.71	2	5.40	6	16.21
Unknown	1	2.71	1	2.70	-	-	2	5.41
Total	22	59.46	11	29.73	4	10.81	37	100

4.3.2 FINENESS MODULUS

Nothing is stated in the Ethiopian Standard concerning the fineness modulus of coarse aggregate samples. However CRD(Corps of Engineers CRD-C 104 Method of Calculation of the Fineness Modulus of Aggregates) states that the fineness modulus of a good concrete coarse aggregate falls in the range between 5.5 and 8.5. The result of the fineness modulus of the fine aggregate samples is summarized in Table 4.11 (Annex B2, Annex B3, AnnexB4).

Table 4.11 Distribution in number and percentage of Coarse Aggregate Samples

Fineness Modulus	Number and percentage of Samples						Total	
	In & around A.A		Out of A.A		Source Unknown			
	No.	%	No.	%	No.	%	No.	%
Below 5.5	-	-	-	-	2	5.71	2	5.71
B/n 5.5 and 8.5	21	60	10	28.57	2	5.72	33	94.29
Above 8.5	-	-	-	-	-	-	-	-
Total	21	60	10	28.57	4	11.43	35	100

Fineness Modulus range : **5.59 – 7.69**

Average : **6.87**

4.3.3 GRADATION OF THE SAMPLES

To see whether the samples satisfy the gradation requirement set by the Ethiopian Standard gradation charts were prepared and their gradation was checked in light of the given requirement in the Standard. The results obtained are summarized in Table 4.12 (Annex C2).

Table 4.12 Distribution in number and percentage of Coarse Aggregate Samples with respect to gradation requirements of the Ethiopian Standard (ES. C. D3. 201).

Condition		Number and percentage of Samples						Total	
		In & around A.A		Out of A.A		Source Unknown			
		No.	%	No.	%	No.	%	No.	%
Not complying with the requirement	**Coarser**	8	22.86	7	20.00	1	2.86	16	45.71
	Finer	4	11.43	1	2.86	2	5.71	7	20.00
	Other[14]	-	-	-	-	-	-	-	-
Complying with the requirement		9	25.71	2	5.71	1	2.86	12	34.29
Total		21	60	10	28.57	4	11.43	35	100

[14] This is a condition where the requirement is not satisfied in more than two sieve sizes in which at least one is above the upper limit and one below the lower limit.

4.3.4 SPECIFIC GRAVITY

The Ethiopian Standard requires that the apparent specifc gravity of a normal concrete aggregate lies b/n the range of 2.4 and 3.0. Table 4.13 (Annex F2) shows the summary of distribution of the specific gravities of the fine aggregate samples in number and percentage.

Table 4.13 Specific Gravity of the Coarse Aggregate Samples with Respect to Requirement of the Ethiopian Standard (ES. C. D3. 201).

Specific Gravity		**Number and percentage of Samples**				**Total**	
Type	**Range**	**In & around A.A**		**Out of A.A**			
		No.	%	No.	%	No.	%
Bulk	Below 2.40	-	-	-	-	**-**	**-**
	2.40 – 3.0	5	38.46	8	61.54	**13**	**100**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**5**	**38.46**	**8**	61.54	**13**	**100**
Bulk (SSD)	Below 2.40	1	6.67	-	-	**1**	**6.67**
	2.40 – 3.0	5	33.33	9	60.00	**14**	**93.33**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**6**	**40.00**	**9**	**60.00**	**15**	**100**
Apparent	Below 2.40	-	-	-	-	**-**	**-**
	2.40 – 3.0	5	38.46	8	61.54	**13**	**100**
	Above 3.0	-	-	-	-	**-**	**-**
	Total	**5**	**38.46**	**8**	61.54	**13**	**100**

Bulk Specific Gravity range : **2.46 – 2.73**
Average **: 2.58**
Bulk (SSD) Specific Gravity range : **2.22– 2.78**
Average **: 2.59**
Apparent Specific Gravity range : **2.56 – 2.89**
Average **: 2.66**

4.3.5 LOOSE UNIT WEIGHT

Nothing is stated in the Ethiopian Standard concerning the unit weight value that concrete aggregates should have. However, ASTM stipulates that the compacted unit weight of good concrete aggregate falls between 1245 (75 lb/ft^3)and 1825 kg/m^3(110 lb/ft^3) (ASTM C29). Table 4.14 (Annex E2) shows the number and percentage of the loose unit weight of the coarse aggregate samples.

Table 4.14 Loose Unit Weight of the Coarse Aggregate Samples with Respect to Requirement of ASTM.

Loose Unit weight (kg/m^3)	**Number and percentage of Samples**						**Total**	
	In & around A.A		**Out of A.A**		**Source unknown**			
	No.	%	No.	%	No.	%	No.	%
Below 1300	3	20	-	-	-	-	3	20
B/n 1300 and 1900	5	33.33	7	46.67	-	-	12	80
Above 1900	-	-	-	-	-	-	-	-
Total	8	53.33	7	46.67	-	-	15	100

Loose Unit Weight range : **1264 – 1590 kg/m^3**

Average : **1392.07 kg/m^3**

4.3.6 COMPACTED UNIT WEIGHT

Similar to the above discussion, the Ethiopian Standard stipulates nothing concerning the unitweight value that concrete aggregates should have. However, ASTM stipulates that the compacted unit weight of good concrete aggregate falls between 1245 (75 lb/ft^3) and 1825 kg/m^3(110 lb/ft^3) (ASTM C29). Table 4.15 (Annex E2) shows the number and percentage of the loose unit weight of the coarse aggregate samples.

Table 4.15 Compacted Unit Weight of the Coarse Aggregate Samples with respect to requirement of ASTM.

Loose Unit weight (kg/m^3)	**Number and percentage of Samples**						**Total**	
	In & around A.A		**Out of A.A**		**Source Unknown**			
	No.	%	No.	%	No.	%	No.	%
Below 1300	-	-	-	-	-	-	-	-
B/n 1300 and 1900	8	53.33	7	46.67	-	-	15	100
Above 1900	-	-	-	-	-	-	-	-
Total	8	53.33	7	46.67	-	-	15	100

Compacted Unit Weight range : **1464 – 1736 kg/m^3**

Average : **1592 kg/m^3**

4.3.7 LOS ANGELES ABRASION

According to the Ethiopian standard (ES C. D3. 201) the maximum loss in mass when coarse aggregate is subjected to abrasion test shall not exceed 50 per cent. Iaddition, ASTM states that a range from 25 to 50% is acceptable for a good aggregate (ASTM- C131 and C 535). Table 4.16 (Annex G1) shows the summary of the Los Angeles Abrasion wear of the coarse aggregate samples used in the study.

Table 4.16 Los Angeles Abrasion (%) wear of the Coarse Aggregate Samples with respect to the requirement of the Ethiopian Standard.

Los Angeles Abrasion wear(%)	Number and percentage of Samples						Total	
	In & around A.A		Out of A.A		Source unknown			
	No.	%	No.	%	No.	%	No.	%
Below 50	13	65	5	25	2	10	20	100
Above 50	-	-	-	-	-	-	-	-
Total	13	65	5	25	2	10	20	100

Los Angeles Abrasion range : **11.00 – 48.84%**

Average : **19.31%**

4.3.8 WATER ABSORPTION

According to the requirement of ASTM the water absorption content of a concrete aggregate should lie in the range of 0.2 to 4 % (ASTM C127). Table 4.17 (Annex F2) shows the summary of the water absorption values of the coarse aggregate samples.

Table 4.17 Water Absorption Capacity of the Coarse Aggregate Samples with respect to the requirement of ASTM.

Water Absorption (%)	Number and percentage of Taste Samples						Total	
	In & around A.A		Out of A.A.		Location unknown			
	No.	%	No.	%	No.	%	No.	%
Below 0,2%	-	-	-	-	-	-	-	-
B/n 0.2 and 4 %	5	33,33	10	66,67	-	-	100	100
Above 4%	-	-	-	-	-	-	-	-
Total	5	33,33	10	66,67	-	-	100	100

Water Absorption Capacity range : **0.31 – 2.55 %**
Average : **1.25 %**

4.3.9 AGGREGATE CRUSHING VALUE

Literature states that the aggregate crushing value of a corarse aggregate sample should be equal to or less than 40% [15]. Fig 4.18 (Annex G1) shows the ditribution in number and percentage of the aggregate crushing values of the coarse aggregate samples.

Table 4.18 Aggregate Crushing Values of the Coarse Aggregate Samples.

Aggregate Crushing Value (Milimoles/litre)	Number and percentage of Taste Samples				Total	
	In & around A.A		Out of A.A			
	No.	%	No.	%	No.	%
Below 40	-	-	4	57.14	4	57.14
Above 40	-	-	3	42.86	3	42.86
Total	-	-	7	100	7	100

Aggregate Crushing Value range : **28 – 43 %**

Average : **36.14 %**

4.3.10 FLAKINESS INDEX

A maximum flakiness index value of 35% is stated in the ASTM for crushed concrete aggregate (ASTM C33). However, there is no requirement stated in the Ethiopian Standardard. Table 4.19 (Annex G1) shows the distribution in number and percent of the flakiness index of the coarse aggregate samples.

Table 4.19 Flakiness Index Values of the Coarse Aggregate Samples with respect to the requirement of the British Standard

Flakiness Index (%)	Number and percentage of Samples				Total	
	Around & in A.A		Out of A.A			
	No.	%	No.	%	No.	%
Below 40	-	-	5	100	5	100
Above 40	-	-	-	-	-	-
Total	-	-	5	100	5	100

Flakiness Index Value range : **11 – 32.68%**

Average : **23.31%**

4.3.11 POTENTIAL ALKALINE AGGREGATE REACTION

Two test samples from out of Addis Ababa were tested for Potential Alkaline reaction using the Chemical method. In the first case Dissolved silica measurement was done and as the result 154 and 96 Milimoles/litre of dissolved silica was found. In the second case Reduction in Alkalinity was measured and 134 and 220 Milimoles/litre alkalinity was found (ASTM C289). According to the ASTM there is no indication that the samples are potentially reactive.

4.3.12 DUST CONTENT

One test sample from Addis Ababa was tested for dust content and it was found to be 14.9 % which is far above the permissible maximum value which is 1.5% (ES C. D3: 201).

4.3.13 CLAY LUMPS CONTENT

Two test samples from out of Addis Ababa were tested for their clay lumps content and a result of 0.2 and 0.3 % respectively was found. The result shows the clay lumps contents of the tested samples were closer to 0.25 % the maximum stated in the Ethiopian Standard.

4.3.14 SILT & CLAY CONTENT

Test was carried out to determine the silt and clay content of one coarse aggregate sample from out of Addis Ababa and a result of 0.6% was found. This value is below the maximum permissible limit which is 1% (ASTM 33/ ASTM C117).

4.3.15 10% FINES VALUE

A 10% fines value test was carried out for two coarse aggregate samples from out side of Addis Ababa and a result of 68 KN was found for both samples. This value is well above the lower which is 50 KN (BS 812 : Part 3).

4.4 ROCK SAMPLES

Test results of four rock samples were considered in this research.

4.4.1 LOOSE UNIT WEIGHT

Since the rock samples were tested to investigate their suitability as a potential source of aggregate production, the requirement set by ASTM for unit weight of coarse aggregate is used here. Nothing is stipulated in the Ethiopian Standard concerning the unitweight value that concrete aggregates should have. However, ASTM stipulates that the compacted unit weight of good concrete aggregate falls between 1245 (75 lb/ft^3)and 1825 kg/m^3(110 lb/ft^3) (ASTM C29). Table 4.20 (Annex E3) shows the number and percentage of the loose unit weight of the rock samples.

Table 4.20 Distribution in number and percent of the Loose Unit Weights of the Rock Samples used in the research.

Loose Unit weight (kg/m^3)	**Number and percentage of Taste Samples**						**Total**	
	In & around A.A		**Out of A.A**		**Source unknown**			
	No.	%	No.	%	No.	%	No.	%
Below 1300	-	-	-	-	-	-	-	-
B/n 1300 and 1900	-	-	3	100	-	-	3	100
Above 1900	-	-	-	-	-	-	-	-
Total	-	-	3	100	-	-	3	100

Loose unit weight range : **1429 – 1464 kg/m^3**
Average **: 1442**

4.4.2 COMPACTED UNIT WEIGHT

Similarly, the Ethiopian Standard stipulates nothing concerning the unitweight value that concrete aggregates should have. However, ASTM stipulates that the compacted unit weight of good concrete aggregate falls between 1245 (75 lb/ft^3)and 1825 kg/m^3(110 lb/ft^3) (ASTM C29). Since the rock samples were tested to investigate their suitability as a potential source of aggregate production, the requirement set by ASTM for unit weight of coarse aggregate is used here. Table 4.21 (Annex E3) shows the distribution in number and percentage of the compacted unit weight of the rock samples.

Table 4.21 Compacted Unit Weight of the Rock Samples.

Compacted Unit weight (kg/m^3)	Number and percentage of Samples						Total	
	In & around A.A		Out of A.A		Source unknown			
	No.	%	No.	%	No.	%	No.	%
Below 1300	-	-	-	-	-	-	-	-
B/n 1300 and 1900	-	-	3	100	-	-	3	100
Above 1900	-	-	-	-	-	-	-	-
Total	-	-	3	100	-	-	3	100

Compacted unit weight range : **1679 – 1700 kg/m^3**
Average : **1690**

4.4.3 WATER ABSORPTION

According to the requirement of ASTM, the water absorption content of a concrete aggregate should lie in the range of 0.2 to 4 % (ASTM C127). Since the rock samples were tested to investigate their suitability as a potential source of aggregate production, the requirement set by ASTM for the water absorption of coarse aggregates is used here.Table 4.22 (Annex F3) shows the summary of the water absorption values of the coarse aggregate samples.

Table 4.22 Water Absorption Capacity of the Rock Samples with respect to the requirement of the Ethiopian Standard.

Water Absorption Range (%)	Number of Taste Samples						Total	
	In & around A.A		Out of A.A		Source unknown			
	No.	%	No.	%	No.	%	No.	%
Below 0,2%	-	-	-	-	-	-	-	-
B/n 0.2 and 4 %	-	-	3	75	-	-	3	75
Above 4%	1	25	-	-	-	-	1	25
Total	1	25	3	75	-	-	4	100

Water absorption capacity range : **1.18 – 6.14 %**
Average : **2.80**

4.4.4 SPECIFIC GRAVITY

The Ethiopian Standard requires that the apparent specifc gravity of a normal concrete aggregate lies b/n the range of 2.4 and 3.0. Since the rock samples were tested to investigate their suitability as a potential source of aggregate production, the requirement set by ASTM for the specific gravity of coarse aggregates is used here. Table 4.23 (Annex F3) shows the summary of distribution of the specific gravities of the rock samples in number and percentage.

Table 4.23 Specific Gravity of the Rock Samples with respect to requirement of the Ethiopian Standard.

Specific Gravity		Number and Percentage of Taste Samples				Total	
Type	Range	In & around A.A		Out of A.A			
		No.	%	No.	%	No.	%
Bulk	Below 2.40	-	-	-	-	-	-
	2.40 – 3.0	-	-	3	**100**	3	**100**
	Above 3.0	-	-	-	-	-	-
	Total	**-**	**-**	**3**	**100**	**3**	**100**
Bulk (SSD)	Below 2.40	-	-	-	-	-	-
	2.40 – 3.0	-	-	3	**100**	3	**100**
	Above 3.0	-	-	-	-	-	-
	Total	**-**	**-**	**3**	**100**	**3**	**100**
Apparent	Below 2.40	-	-	-	-	-	-
	2.40 – 3.0	-	-	3	**100**	3	**100**
	Above 3.0	-	-	-	-	-	-
	Total	**-**	**-**	**3**	**100**	**3**	**100**

Bulk Specific Gravity range : **2.58 – 2.69**
Average : 2.64
Bulk (SSD) Specific Gravity range : **2.64– 2.73**
Average : 2.68
Apparent Specific Gravity range : **2.72 – 2.80**
Average : 2.76

4.4.4 LOS ANGELES ABRASION

According to the Ethiopian standard (ES C. D3. 201) the maximum loss in mass when coarse aggregate is subjected to abrasion test shall not exceed 50 per cent. Table 4.16 (Annex G1) shows the summary of the Los Angeles Abrasion wear of the coarse aggregate samples used in the study.Since the rock samples were tested to investigate their suitability as a potential source of aggregate production, the requirement set by ASTM for Los Angeles Abrasion wear of coarse aggregates is used here. Table 4.24 (Annex G2) shows the summary of the Los Angeles Abrasion wear of the coarse aggregate samples used in the analysis.

Table 4.24 Los Angeles Abrasion (%) wear of the Rock Samples with respect to the requirement of the Ethiopian Standard.

Los Angeles Abrasion wear (%)	Number and Percentage of Samples						Total	
	In & around A.A		Out of A.A		Source Unknown			
	No.	%	No.	%	No.	%	No.	%
Below 50	1	33.33	2	66.67	-	-	3	100
Above 50	-	-	-	-	-	-	-	-
Total	1	33.33	2	66.67	-	-	3	100

Los Angeles Abrasion range : **13.26 – 30%**

Average : **18.85**

4.4.6 SOUNDNESS

Tests were carried out to assess the soundness of the three rock samples from different parts of the country out of Addis Ababa. Soundness was determined using Sodium Sulphate and the results obtained were 2.09, 3.10 and 5.62 % with an average value of 3.60. This is a good result as far as the 12% maximum permissible limit stated in the ASTM C33 and in the Ethiopian Standard is concerned. The values are given in Annex G2.

4.4.7 SULPHATE AND CHLORIDE CONTENTS

Tests were carried out to determine the sulphate and chloride contents of a rock sample brought from a dam site out side Addis Ababa. A 24 mg/lt sulpahte and 66mg/lt chloride contents were found to be present in the rock sample considered (Annex G2). Though, it is not stated in the Ethipian Standard the British standard states a maximum value of 330mg/lt.

4.4.8 POTENTIAL ALKALINE- AGGREGATE REACTION

Three rock samples were tested to assess their potential for alkaline- aggregate reaction. From the test the dissolved silica and chloride contents of the samples were determined. 72, 76 and 92 Milimoles/litre of dissolved silica were found in the determination of dissolved silica content and 180, 164 and 184 Milimoles/litre of reaction in alkalinity were found in the determination of reaction in alkalinity test. According to the ASTM there is no indication that the samples are potentially reactive.

4.4.9 FLAKINESS INDEX

From the test carried out to determine the flakiness indices of samples collected from two rocks out of Addis Ababa, flakiness indices of 30 and 33 % were obtained. According to the 35% maximum permissible limit stated in the ASTM C33 the results obtained were in compliance with the criterion (Annex G2).

5. ANALYSIS AND DISCUSSION

5.1 TESTS ON AGGREGATES

It is necessary and worthwhile to determine the engineering properties of aggregate sources when assessing their quality, which gives us the chance to use those materials to their maximum potential. Following the results summarized in the previous chapter, the discussion made on the results obtained is presented in this chapter.

5.1.1 COARSE AGGREGATES

Out of the total 37 coarse aggregate samples, aggregtes sizes 37.5, 19.5 and 13.5 constitute 59.46%, 18.91% and 16.21% of the total samples considered in this research respectively. This gives an indication that aggregate sizes of 37.5mm are dominantly used in concrete production in the Ethiopian construction industry.

As it is shown in Table 5.1 one sample tested for dust content failed to satisfy the requirement. It would be difficult to characterize the quality of aggregates from this single observation. However, the dust content of the sample was too far above the maximum limit stated in standards. This gives an indication that aggregates produced in Addis Ababa are susceptible to dust contamination.

The analysis of the samples shows that 65.71% of the coarse aggrgates couldn't satisfy gradation requirement and 40 % of the aggregates had larger value of aggregate crushing value. Though, gradation of aggregates is one of the most important quality parameters that predominantly influence the properties of a concrete, the results of this research depicts that more than half of supplied aggregates don't meet this requirement.

50% of the samples had a clay lumps content more than that stipulated in the standard. It is a known fact that presence of clay lumps has significant influence on the strength of the resulting concrete. In addition, 40% of the samples had an aggregate crushing value which is above stated in the standard. Clay lumps content is an attribute dependent on the production process of coarse aggregates. There fore, it demands the concern of the coarse aggregate producer to use a production process which reduces the amount of clay lumps in the aggregate. In addition, about 6 and 7% of the samples had unacceptable bulk specific gravity (SSD) and a fineness modulus values out of the acceptable range respectively. This is good indication that more than 90% the aggregates produced in the country are good for concrete as far as their bulk specific gravity (SSD) and fineness modulus values are concerned.

The results of the remaining tests carried out on the coarse aggregate samples indicate that 100% of the samples were fit for concrete production as far as their test result values of Los Angeles Abrasion, Compacted Unit Weight, Bulk Specific Gravity, Apparent Specific Gravity, Water Absorption, Flakiness Index, Potential Alkaline aggregate reaction, silt and clay content and 10% fines values are concerned.

Of the total number of tests carried out, the results of 44% of the tests were not incompliance with the requirements of standards. This is an indication that more than 40% of the tests carried out on the aggregates supplied for concrete production in the country are not met by the concrete aggregates. Further, out of the 44% of the tests at which the aggregates fail to satisfy requirements, 71% of the tests attribute to the property of the aggregate which is not related to the property of the parent rock. This is an indication that more than about 70% of the failure of the coarse aggregates to meet requirements of standards is not mainly related to the property of the parent rock but to the production process and handling of the aggregates in general.

Table 5.1 Summary of the percentage of coarse aggrregate samples failed to satisfy requirements.

Order	Test	Percentage failed
1	Dust Content	100.00
2	Gradation/sieve analysis	65.71
3	Clay Lumps Content	50.00
4	Aggregate Crushing Value	40.00
5	Loose Unit weight	20.00
6	Bulk Specific Gravity (SSD)	6.67
7	Fineness Modulus	5.71
8	Los Angeles Abrasion	-
	Compacted Unit Weight	-
	Bulk Specific Gravity	-
	Apparent Specific Gravity	-
	Water Absorption	-
	Flakiness Index	-
	Potential alkaline aggregate reaction	-
	Silt and Clay Content	-
	10% fines value	-

Table 5.2 shows the types of tests carried out on the aggregates and the respective percentage of the aggregate samples tested. About 95% of the samples were checked for gradation. A Los Angeles Abrasion test was carried out for about 55% of the samples. The loose unit weight, compacted unit weight and water absorption of about 40 % of the samples were measured. As it is shown in the table that the bulk specific gravity (SSD) of 38% of the samples was determined and determination of bulk and apparent specific gravities of about 35 % of the samples were carried out. In addition, the aggregates crushing values and flankiness index of about 13 % of the samples were determined. Finally, the clay lumps content, potential alkaline aggregate reaction and 10% fines values were determined only for about 5% of the samples. In addition, only about 3% of the samples were checked for dust content and silt and clay content

Table 5.2 Summary of the number of tests carried out on the collected coarse aggregate samples

Order	Test	Number Of Tested Samples	Percent of the total
1	Gradation/sieve analysis	35	94.59
	Fineness Modulus	35	94.59
2	Los Angeles Abrasion	20	54.05
3	Loose Unit weight	15	40.54
	Compacted Unit Weight	15	40.54
	Water Absorption	15	40.54
4	Bulk Specific Gravity (SSD)	14	37.84
5	Bulk Specific Gravity	13	35.14
	Apparent Specific Gravity	13	35.14
6	Aggregate Crushing Value	5	13.51
	Flakiness Index	5	13.51
7	Clay Lumps Content	2	5.41
	Potential alkaline aggregate reaction	2	5.41
	10% fines value	2	5.41
8	Dust Content	1	2.70
	Silt and Clay Content	1	2.70

5.1.2 FINE AGGREGATES

Two samples tested for soundness failed to satisfy the requirement as shown in Table 5.3. However, the values of the soundness of the samples were not too far above the maximum limit stated in standards. Depending on the specification of the concrete these aggregates might be used for concrete production.

The analysis of the samples shows that 91% of the coarse aggregates had loose and compacted unit weight values which were not in the range stated in standards and literature. This gives an indication that about 90% of the fine aggregates supplied in the country have a unit weight which is not suitable for quality concrete production.

Gradation of aggregates is one of the most important quality parameters that predominantly influence the properties of a concrete. However, the result of this research shows that about 56 percent of the samples couldn't satisfy gradation requirements. This has an implication that more than 50% of the fine aggregates supplied to the industry have quality problems as far as gradation requirements are concerned.

40% of the samples had a bulk specific gravity (SSD) out of the stated range for normal concrete aggregates. This is an indication that about 40 % of the fine aggregates supplied in the country have unacceptable bulk specific gravity for concrete production.

30% of the samples had a bulk specific value and a silt and clay content which are not in accordance with requirements. Both of them are important parameters influencing the properties of concrete significantly.

Only about 5% of the samples had unacceptable value of organic impurity and a fineness modulus value out of the acceptable range respectively. This is good indication that about 95% the aggregates produced in the country are good for concrete as far as their organic impurity and fineness modulus values are concerned.

The results of the remaining tests carried out on the fine aggregate samples indicate that 100% of the samples were fit for concrete production as far as the test result values of apparent specific gravity, clay lumps content and chloride contents of the samples are concerned.

Of the total number of tests carried out, the results of 77% of the tests were not incompliance with the requirements of standards. This is an indication that more than 75% of the tests carried out on the aggregates supplied for concrete production in the country are not met by the concrete aggregates. Further, out of the 77% of the tests at which the aggregates fail to satisfy requirements, 60% of the tests attribute to the property of the aggregate which is not related to the natural quality of the fine aggregates. This is an indication that about 60% of the failure of the fine aggregates to meet requirements of the standards is not mainly related to the natural quality of the aggregates; rather it is related to the production process and handling of the aggregates in general.

However, had the material been passed through some treatment to make it suitable for concrete work it wouldn't have failed to meet these standard requirements. This signifies the importance of treating fine aggregates properly before they are used for concrete production..

Table 5.3 Summary of the percentage of fine aggrregate samples failed to satisfy requirements.

Order	Test	Percentage failed
1	Soundness	100.00
2	Loose Unit weight	91.30
	Compacted Unit Weight	91.30
3	Gradation/sieve analysis	56.52
4	Bulk Specific Gravity (SSD)	40.00
5	Silt and Clay Content	30.77
6	Bulk Specific Gravity	30.00
7	Water Absorption	20.00
8	Fineness Modulus	4.35
9	Organic Impurity	4.26
	Apparent Specific Gravity	-
	Claylumps content	-
	Chloride content	-

Table 5.4 shows the types of tests carried out on the aggregates and the respective percentage of the aggregate samples tested. All the samples considered were tested for organic impurity. More than 95% of the samples were checked for gradation and more than 80% of the samples were checked for silt and clay content. The loose unit weight and compacted unit weight of about 49 % of the samples were determined. The bulk specific gravities, the apparent specific gravity and water absorption of about 22 percent of the fine aggregate samples were also determined.

Only about 4% of the samples were checked for soundness and clay lumps content. In addition only one sample (2.13%) out of the total 36 samples is was checked for chloride content.

Table 5.4 Summary of the number of tests carried out on the collected fine aggregate samples

Order	Test	Number Of Tested Samples	Percent of The total
1	Organic Impurity	47	100.00
2	Gradation/sieve analysis	46	97.87
	Fineness Modulus	46	97.87
3	Silt and Clay Content	39	82.98
4	Loose Unit weight	23	48.94
	Compacted Unit Weight	23	48.94
5	Bulk Specific Gravity (SSD)	10	21.28
	Bulk Specific Gravity	10	21.28
	Apparent Specific Gravity	10	21.28
	Water Absorption	10	21.28
6	Soundness	2	4.26
	Claylumps content	2	4.26
7	Chloride content	1	2.13

5.1.3 ROCK SAMPLES

All the rock samples tested were in compliance with requirements except 25% of the tested samples that failed to satisfy the requirement set concerning water absorption content as it is shown in Table 5.5. The total number of samples considered in this research was 4.

It is apparent that the number of rock test samples was too small when compared to the number of test samples of the fine and coarse aggregates used in this research. However, this is practical in reality. In actual situations, a number of aggregate test samples might be tested which are collected from a certain quarry site. However, the base rock of that quarry need not be tested as frequently as the aggregate products. This supports the idea that, though the number of the collected test results of the rock samples is small, it is sufficient to give indication concerning the handling of rocks in the production of coarse aggregates in the Ethiopian Construction Industry.

Table 5.6 shows the types of tests carried out on the aggregates and the respective percentage of the aggregate samples tested. Water absorption of all the rock samples were determined. Tests to determine the loose unit weights, the compacted unit weights, the bulk specific gravity (SSD), the bulk specific gravity, apparent specific gravity, Los Angeles abrasion and potential alkaline aggregate reaction of 75 % of the rock samples were carried out.

The loose unit weight and compacted unit weight of about 49 % of the samples were determined. The flakiness index and soundness of 25 percent of the rock samples were also determined. In addition, sulphate and chloride contents of 25% of the rock samples were determined.

Table 5.5 Summary of the percentage of the rock samples failing to satisfy requirements.

Order	Test	Percentage failed
1	Water Absorption	25
2	Loose Unit weight	-
	Compacted Unit Weight	-
	Soundness	-
	Bulk Specific Gravity (SSD)	-
	Bulk Specific Gravity	-
	Apparent Specific Gravity	-
	Los Angeles Abrasion	-
	Sulphate Content	-
	Chloride content	-
	Potential Alkaline Aggregate Reaction	-
	Flakiness Index	-

Table 5.6 Summary of the number of tests carried out on the collected coarse aggregate samples

Order	Test	Number of Samples	Percent of the total
1	Water Absorption	4	100
2	Loose Unit weight	3	75
	Compacted Unit Weight	3	75
	Bulk Specific Gravity (SSD)	3	75
	Bulk Specific Gravity	3	75
	Apparent Specific Gravity	3	75
	Los Angeles Abrasion	3	75
	Potential Alkaline Aggregate Reaction	3	75
3	Flakiness Index	2	50
	Soundness	2	50
	Sulphate Content	1	25
	Chloride content	1	25

5.1.4 COMPARISON B/N THE FINE AND COARSE AGGREGATE SAMPLE RESULTS

While collecting the results of the test samples for this research it was observed that the number of fine aggregate samples submitted to the laboratories exceeds the number of coarse aggregate samples submitted for testing. With the same token the number of fine aggregate samples considered in this research exceeds the number of coarse aggregate test samples.

13 tests were carried out for the fine aggregates and 16 tests were carried out for the coarse aggregate samples. This is an indication that the construction industry in Ethiopia is more concerned on the quality test of the coarse aggregates than the quality test of the fine aggregates.

With respect to compliance, 44% of the total coarse aggregate samples were not in compliance with requirements and 71 % of these tests attribute to the property of the aggregate which is not related to the properties of the parent rock. Further, 77% of the fine aggregate test samples considered failed to satisfy requirements and 60 % of these tests attribute to the property of the aggregate which is not related to the nature of the fine aggregate. These results show that fine aggregates supplied to the construction industry have lesser quality less than the coarse aggregates supplied. In addition, the results also shows that majority (equal to or more than 60%) of the quality problems both for the fine and coarse aggregates attributes to the production process and the handling of these aggregates in general.

5.2 MIX DESIGN

To see the effect of inconsistency of the quality of the supply of aggregates on proportioning concrete, trial mix designs were prepared for concretes made with aggregates of different properties. It is known that, there is no local mix design procedure in Ethiopia. However, it is believed that the ACI mix design procedure is used in the majority of construction projects in Ethiopia. Therefore, the analysis made in this research was entirely based on the ACI method of mix design [28].

Hence, different trial mix designs were prepared taking into consideration the different qualities that were practically found in the collected test samples in this research. Finally, cost calculations were performed using the resulted different mix proportions. The mix designs were carried out taking 25 MPa as the required charcteristic compressive strength and taking the slump to be 50mm. The analysis was made using only the properties of those aggregate samples which were collected from Addis Ababa and its surrounding. In addition, in the trial mix design only the properties of samples which were incompliance with standards were considered. Of all the samples that their sources were from and around Addis Ababa, only 3 fine aggregate and 4 coarse aggregate samples were found to be in compliance with the requirements of different standards. Therefore, mix designs carried out only using these seven aggregate samples.

5.2.1 PROPERTIES OF AGGREGATES USED IN THE ANALYSIS

Table 5.7 Properties of the fine aggregate samples used for the mix design

Sample	Fineness Modulus	Bulk Specific Gravity(SSD)
F10	2.80	2.34
F21	2.75	2.34
F28	2.59	2.30

Table 5.8 Properties of the coarse aggregate samples used for the mix design

Sample	Bulk Specific Gravity (SSD)	Unit weight (kg/m^3)	Maximum Aggregate Size
C9	2.56	1505	37.5
C15	2.78	1671	37.5
C16	2.74	1679	37.5
C18	2.52	1464	37.5

5.2.2 TRIAL MIX DESIGN FOR THE ANALYSIS

Here acceptable and average values found from the collected sample results were used for the trial mix design

Required Minimum compressive cube strength of the Concrete	: 25 MPa (used for beams and reinforced walls)
Maximum aggregates size	: 40 mm
Slump	: 25 – 100 mm
Air content	: 1%
Standard deviation	: Unknown
Air entrainment	: None
Maximum cement content	: 550 kg/m^3
Minimum cement content	: 320 kg/m^3
Maximum water: cement ratio	: 0.60
Cement Type	:Mugher PPC
Specific gravity of the cement sample	: 3.15

5.2.3 SAMPLE TRIAL MIX DESIGN PROCEDURE USED IN THIS RESEARCH

Mix design for Fine aggregate sample F10 and coarse aggregate sample C9

(Designation of the samples is given in Annex A)

Step 1

Slump = 50mm (25 – 100 mm)... [Table A1.5.3.1 [28]]

Step 2

Maximum aggregate size = 4**0mm (37.5 mm)**

Step 3

Non air entrained

Air content = **1% ………..**…………………….……………………...….. **Table A1.5.3.3** [28]

Water content = **181 kg/m^3** …………………………………...………. **Table A1.5.3.3** [28]

Step 4

Minimum compressive cube strength = **25MPa;** Standard deviation (s) = **Unknown**

Minimum cylinder compressive strength (f_c') = 0.8 x Minimum compressive cube strength

= 0.8 x 25 = **20 MPa**

Average cylinder compressive strength f_{cr}' = f_c' + 7 MPa (Unknown standard deviation)

Therefore, = 20 + 7 =**27 MPa**

Therefore w:c ratio = 0.58 > 0.60 (maximum permissible) ,Take **0.58**

Step 5

Cement content = 190/0.58 = 327kg/ m^3> 320(Minimum required), Take **327 kg/ m^3**

Step 6

Fineness modulus of fine aggregate = 2.80, by interpolation approximate value of percentage of coarse aggregate is **0.71**………........................……………………Table A1.5.3.6 [28]

Therefore, weight of coarse aggregate is 0.71 x 1505 = **1069 kg/** m^3

Step 7

Absolute Volume Method

Volume of water	181/1000	=	0.181 m^3
Solid volume of Cement	327/(3.15 x 1000)	=	0.104 m^3
Solid volume of Coarse aggregate	1069/(2.56 x 1000)	=	0.418 m^3
Volume of entrapped air		=	0.010 m^3
Total			**0.713 m^3**

Therefore, solid volume of fine aggregate required = 1 – 0.713 **= 0.287 m^3**

And weight of fine aggregate = 0.287 x 2.34 x 1000 **= 672kg/ m^3**

Since the moisture contents of the samples were not known it was assumed in the analysis that the samples are in a saturated surface dry condition. To this effect no adjustments were done for the calculated proportions.

Table 5.9 Summary of Proportions of Constituents of the resulting Concrete

Constituent	Content (kg/ m^3)
Water	181
Cement	327
Coarse aggregate	1069
Fine aggregate	672
Density of the fresh concrete	**2235**

The material cost of a 1m^3 of concrete made with the above proportion is shown in the table below (Table 5.10):

Table 5.10 Cost of the Concrete Mix (in A.A. June 2005 market price)

Constituent	Unit	Quantity	Shrinkage & Contingency	Total Quantity	Unit Price (Birr)	Total Price (Birr)
Water	m^3	0.181	35%	0.244	1.50	0.37
Cement	Kg	327	35%	441.45	0.7555	333.52
Coarse aggregate	m^3	0.287	35%	0.478	165	93.11
Fine aggregate	m^3	0.418	35%	0.474	135	52.31
				Total		**479.20**

Table 5.11 Summary of the mixdesign result of the samples and the total material cost of the resulting concrete used in the research

No.	combination		Content(kg/ m^3)				Cost In A.A. (Birr/m^3)
	Coarse	Fine	Water	Cement	Coarse Aggregate	Fine Aggregate	
1	C9	F10	181	327	1069	672	**479.20**
2	C15	F10	181	327	1186	650	**479.56**
3	C16	F10	181	327	1192	632	**480.03**
4	C18	F10	181	327	1039	686	**479.09**
5	C9	F21	181	327	1121	625	**480.07**
6	C15	F21	181	327	1245	601	**480.57**
7	C16	F21	181	327	1251	580	**480.93**
8	C18	F21	181	327	1091	636	**479.97**
9	C9	F28	181	327	1100	633	**479.85**
10	C15	F28	181	327	1222	612	**480.12**
11	C16	F28	181	327	1227	599	**480.70**
12	C18	F28	181	327	1070	644	**479.63**

Generally, the cost that aggregates contribute to the total in place cost of concrete is relatively low. Costs of aggregates are usually governed by availability, cost of processing, and distance transported. Frequently, there are other factors which if properly considered, can have a much greater economic or environmental impact than direct aggregate cost. Some of the important factors are aggregate quality (cleanness, durability) particle shape, gradation, water requirements, cement requirements, density and yield, effect on concrete strength, and effect on placeability and finishability. Understanding of these factors and their intraction when used in the proportioning of concrete mixtures can significantly affect the cost of inplace concrete. Though it is difficult to deduce the cost impact of the variability of the supply of aggregates in concrete production quantitatively, it is apparent from the above discussion that the use of quality and uniform aggregate significantly reduces both material and placing costs of concrete.

Aggregates may vary greately in composition due to geologic factors involved in the formation, subsequent deformation, and mineralogy of the source material. Other compositional differences in the aggregates may be due to the process used in crushing, sizing and cleaning. There can be a wide range in the various physical and chemical properties among aggregate sources as well as variation in the properties of an aggregate from a single source can affect the performance of freshly mixed concrete.

Basic physical and chemical characteristics of aggregates can not generally be altered by processing, although the quantities of certain deleterious particles can be reduced. Aggregate characteristics that can be controlled include grading, moisture content, cleanliness, removal of abnormally light particles, and to some degree, particle shape. Economic factors usually determine the degree to which processing can be directed to produce the best compromises between desirable aggregate properties and economy.

In the analysis, the proportion of coarse aggregates and fine aggregate calculated for the three fine aggregate and the four coarse aggregate samples to satisfy a common specification, ranges as follows:

Coarse aggregate : 1039 kg/m^3 – 1251 kg/m^3
Difference : 212 kg/m^3
Fine aggregate : 580 kg/m^3 – 686 kg/m^3
Difference : 106 kg/m^3

Cost : 479 birr/m^3 – 480.93 birr/m^3

Difference : 1.93 birr/m^3

The mix design result has shown that even among the aggregates which were supplied to Addis Ababa and which satisfy requirement there is difference in their property. Since normally the aggregates supplied are not unifrom and consistent, to get the required strength the concrete producer has to make mix design to all the available aggregates. However, this is practiacally impossible and requires additional financial and time resource. This signifies the importance of standardization in aggregate production.

Since it is difficult to attain the required strength with the available construction materials,i.e., it is impractical to prepare a mix design for such a non uniform and non consistent supply, the concrete producers resort :

1. to have a conservative mix design;
2. to increase the amount of cement in the concrete (thought this might not help unless the mixdesign is done properly);
3. to use cements which gain strength faster than the specified one; this includes the use of OPC inplace of PPC.

However, these options even if they might help to produce a concrete that satisfies requirements, they incure addtional cost to the concrete producer which has significant impact especially in the profit that the concrete producer or the contractor anticipates.

5.3 AGGREGATE PRODUCTION

Controlling the production process should be given first priority when beginning on the road to producing a concrete of good quality. It is here that all inputs are measured, evaluated and controlled so that the product conformity and uniformity can be predicted. Once a unform product appears on the last belt of the crusher plant doesn’t mean that the work is over. Unless the transportation and handling on sites is considered, the uniformity of the product can also be destroyed at all.

It is unfortunate that the material which is naturally of good quality might not be up to the standard at all if it is not handled properly afterwards. Whatever good quality the naturally available material has, its final quality after all depends on the extraction method employed. Each and every process that involve in the production process of fine and coarse aggregate influences the final aggregate product and ultimately the concrete produced by these aggregates.With the aggregate production, the quality of the aggregate products can be influenced, but the raw material - the gravel or rock – may have characteristics which can not be modified by the production process.

It was observed in this research that in Ethiopia, aggregate producers don't have the knowledge they need to have concerning the quality of the material they are producing. Due to this reason it is difficult to get an aggregate of acceptable quality. In addition, the naturally available good quality resource is being used inefficiently and not optimally. Further, the need for knowledge is increasing as conventional concrete aggregate supplies are becoming depleted especially in the urban areas, and environmental aspects prevent the use of existing sources. Therefore , the importance of having trained aggregate producers in the Ethiopian construction industry can not be overemphasized.

In developed countries like Germany they use natural gravel for production of normal strength concrete. On the other hand, unlike the situation in Ethiopia, crushed aggreagte is employed in the developed countries, only for high strength and special concrete production. This is so important for the proper utilization of resources.

The test results which were analysed in this research have signified that good quality natural sand is available in many parts of the country; however, the sand deposite may not have been laid uniformly, meaning a potential change in quality and in size is possible. This signifies the importance of treating fine aggreagte before it is employed for concrete production.

The test results and researches carried out in local concrete making materials in different parts of Ethiopia have shown that, good quality raw material is available for coarse aggregate production. Therefore, to properly make use of this quality of the raw materials, the production process should be carried out in a planned and knowledgeable way. Especially, in blasting the mining area it is preferable to employ a bench system rather than blasting a rock which has more than 20 meters high in one go. This method is useful especially for the proper utilization of resources and it significantly reduces environmental impacts.

Though, engineering geological maps are important for a planned and efficient utilization of natural resources it is hard to say there is one in Ethiopia except for some selected cities and some dam sites. Therefore, unless there is a national engineering geological map, it is difficult to properly utilize the natural aggregate resources of the Country.

5.4 SUPPLY AND DEMAND

The primary information shows that according to the current trend, the existing supply will continue to cover with an averge of 47% of the total coarse aggregate demand of Addis Ababa for the coming few years. This shows the importance of identification of potential resources and future planning.

Meeting the huge needs for infrastructure in the developing world with current technology will require continual substantial increases in cement production. Cement demand in 2020 is expected to be from 120 to 180 % higher than in 1990 [48]. Most of this growth will be due to developing countries. Answering social and economic demands of developing countries is in the path of sustainable infrastructural development. And doing so with current technology will require substantial increase in cement production. This is an indication that, Ethiopia being one of the developing countries it is viable that its yearly cement demand increases inline with the above prediction.

According to the results of this research, the quality control of the production process in the existing aggregate productions plants is not up to the standard. In addition, when they are compared to the rate of expansion of cities and the demand of infrastructure development in Ethiopia, it is doubtful that the existing production plants would meet the demand both in the aspects of quality and quantity. To meet the future demand of aggregate,potential aggregate sources should be identified and be prepared for future use.

5.5 STANDARDIZATION

There is no a standard written procedure as to how to handle aggreagtes while the production process is going on and also how to handle these materials in construction projects in the utilization of aggregates for concrete production. In addition, the number of requirements stated in the Ethiopian Standard is not sufficient to control the quality of fine and coarse aggregates in the Ethiopian construction industry.

There is no standard that the coarse or fine aggregate producers should follow in the production of these aggregates. And there is no a standard guide line to control the production process on the side of the statutory bodies.

Interviews and observations made in this research have shown that there is no licensing guideline for sand and aggregate producers in Ethiopia especially with respect to the quality of the material produced. The potential investors in the area are required to submit proposal of their investment. However, there is no control as to whether the producers follow a quality control procedure in the production process or not. In addition, only paper work is done when renewing their license every year.

In Germany, there are procedures that aggregate producers are expected to follow in aggregate production. In addition, they have to renew their license twice in a year. The responsible bodies might come at any time and see whether the producers are following the standard procedures or not.

5.6 APPLICATION OF READY MIXED CONCRETE IN THE CONSTRUCTION INDUSTRY

Unlike the trend in Ethiopia where concrete is normally produced on site, in most developed and developing countries ready mixed concrete production plants are responsible for the production of the major portion of the total concrete produced in their country. Today, ready mixed concrete offers high-tech solutions to the needs of the construction industry. It allows building of ever longer bridges, ever higher buildings, tunnels, dams, etc.

In the German construction industry ready mixed concrete constitutes about 87% of the total concrete produced excluding precast concrete and it consumes about 47% of the total cement consumed in the country. The following table shows production, production per capita, cement consumption and % of ready- mixed concrete in different countries in the world.

Table 5.12 Ready-mixed concrete production figures in different countries
(**Source:** European Ready Mix Concrete Organization, European Ready-Mixed Concrete Industry Statistics, Year 2003, July 2004.)

Country	**Total Production X 10^6 m^3**	**Production per Capita (m^3/capita)**	**Cement Consumption X 10^6 ton**	**% of cement to Ready-mixed concrete produced**
USA	310.00	1.06	113.83	74.00
Spain	81.00	1.96	46.22	50.00
Italy	72.90	1.27	43.48	48.70
Germany	46.90	0.57	28.90	46.70
Russia	35.00	0.24	36.41	-
France	34.8	0.58	20.68	47.00
Turkey	28.20	0.40	28.11	30.00
United Kingdom	22.00	0.37	13.24	54.00

The cost of ready-mixed concrete, since it is a bought commodity, may be some what higher than that of site-mixed concrete, but this is often offset by savings in site organization, in supervisory staff, and in cement content. The later arises from better control so that a smaller allowance need be made for chance variations.

The observations made concerning ready mixed concrete production and utilization in Germany is summarized below. When compared to on site mixed concrete, ready mixed concrete has the following advantages:

1. **Service**

   Ready mixed concrete provides consumers with good service quality. This advantage is due to the following reasons:

   - The availability of concrete truck mixers allow delivery rates to be kept under control and optimized;
   - Due to dense network of ready mixed plants it is always possible to get a ready-mixed plant near a work site;
   - Special services for difficult work sites: pumps, conveyors, night deliveries etc.
   - Availability of concrete of any grade according to the client's requirements;
   - Durable and affordable;
   - Environmentally friendly.

2. **Quality**

   Ready mixed concrete guarantees quality due to the following reasons:

   - The materials of which it is made are themselves subject to stringent quality requirements;
   - Rigorous quality control is carried out thorough out the manufacturing and delivery process;
   - The formulation and manufacturing of the concrete are covered by the numerous national quality standards.

3. **The Delivery Solutions**

   Ready-mixed concrete meets a great variety of needs in terms of technical sophistication, ease of use and design due to the following reasons:

- the ability of test centers and laboratories to do research into and industrialize ever more innovative concrete that is in tune with trends in architecture and the construction industry
- the use of multiple combinations of cement, aggregates and admixtures stored on production plant sites.

4. **Benefit at site for the Customer/ Contractor**

- Deliveries of ready-mixed concrete can be taken directly from the ready-mix plants or the concrete can be delivered to worksites by concrete mixer trucks;
- The pace of can be adapted to the customer's needs and can change from one hour or day to the next;
- The use of ready-mixed concert keeps worksite nuisance (dirt, congestions, noise, etc.) to minimum levels;
- Elimination of procurement and hiring of plants and equipments;
- Wastage of materials as site is avoided;
- Labor and supervisory cost associated with production of concrete is lowered;
- Time required for concreting is greatly reduced;
- Noise and dust pollution as site is reduced;
- Organization at site is more streamlined;
- No storage space required either for raw materials or for the mix.

All the above mentioned facts signify the advantages of using ready mixed concrete production plants in place of on site concrete production. As the results found in this research indicated, the concrete making materials produced in the Ethiopian construction industry lacks uniformity, consistency and don't meet requirements. This imposes additional burden on the contractor besides the management and quality control of his project.

However, the Contractors in the Germany construction industry concentrate on the management aspect of their work rather than worrying about concrete production on site. This gives good lesson to the Ethiopian construction industry. Though it needs a detailed analysis concerning the financial benefit of using ready- mixed concrete in place of on site mixed concrete, it is clear from the discussion made above that, utilization of ready-mixed concrete is important for the efficiency and effectiveness of the construction industry in general and the handling of concrete making materials in particular.

6. CONCLUSION

Effectiveness and efficiency of the construction industry of a country is a key aspect for today's competitiveness in the business world. It is a known fact that, resources planning and management is one of the most important parameters for competitiveness and profitability in today's construction technology. One important aspect of resources management is management of construction materials in construction projects.

Materials management is an important element in project planning and control. Further, one important aspect of materials management is handling of construction materials. Concrete is one of the construction materials used in almost all construction works. Concrete being one of the important constituents of many of the construction projects, in addition to its subjectivity to variability, requires a close and thorough care and management in construction projects.

The constituents of concrete which most of them are naturally occurring materials are subjected to a wide range of variability. The first constituent, water, is a relatively non variable and usually available in a condition to be used for concrete readily. The second constituent, cement, is also a factory product that it is relatively easy to control its production process and its quality. However, the third constituents of concrete, which are coarse and fine aggregates, are usually naturally occurring that they are subjected to a wide range of variability.

Coarse and fine aggregates constitute the majority of the volume of a concrete. Especially, fine aggregates are used directly from their source or quarry with out given any kind of treatment, that might help to keep them in line with standard quality requirements. Some times contractors wash fine aggregates before using it for concrete if the condition obliges them to do so. To analyze the situation of handling of concrete making materials in Ethiopia this research has been conducted and the results found are summarized as follows. The methods used for data collection were on site observation, material test data collection, interview and data collection in Ethiopia and Germany.

It was observed in this research that handling of fine aggregates in the Ethiopian construction Industry context is not mechanized. Handling of these materials starting from the production process to the storing and use of the aggregates in construction sites is very poor. In addition, the quality control aspect is too weak that the specifications prepared and the tests required by supervising Engineers are too loose.

This is a result of two possible reasons. The first one is that there is no organized fine aggregates supplier in the country that the contractors have no choice except accepting whatever quality the supplied fine aggregates has. The second reason is that responsible government bodies and supervising engineers don't make tight control over contractors in the aspcts of materials quality. This was apparent in construction projects where the supervisors were expatriates and asked the contractors to supply only materials, which can satisfy their requirements. It was observed in these situations that the contractors were doing their best to acquire construction materials, which are to the standard. There fore, had there been tight control on the quality of the supplied materials the situation in this country could have been improved considerably.

Handling of coarse aggregates in the Ethiopian construction industry is no different from that of handling of fine aggregates. Quarry site selection is usually done with out prior detail site investigation and assessement of the availability and properties of the bed rock. In addition, future expansion of nearby towns and environmental impacts of the crushing plant are not usually taken in to consideration in locating the quarry site. This has resulted in wastage of resource and unnecessary expense in addition to the environmental impact it has imposed.

In addition, there has always been a supply and demand gap in construction materials especially, in cements and coarse aggregates in the Ethiopian construction Industry. Unless measures are taken it would be a hindrance to the development of the economy of the country. For example in Addis Ababa alone, it has been estimated that there is an average of above 50% supply and demand gap of coarse aggregates.

According to this research more 44%of the coarse aggregate samples considered and 77% of the fine aggregate samples considered couldn't satisfy requirements set by standards. In addition, more than 60% of the test that the samples failed to satisfy don't attribute to the natural quality of the materials. Further, researches carried out in different parts of Ethiopia have also shown that the naturally available material have quite acceptable quality to be used as a concrete making material. This indicates that the reason why concrete making materials fail to comply with requirements attributes to the handling of the materials in the construction industry but not to the unavailability of materials satisfying requirements in Ethiopia.

In addition, since the supply of coarse and fine aggregates vary widely from one to the other the contractors are always in problem of producing concrete which satisfies especially, strength requirements. Therefore, if they have to produce a concrete which satisfies the requirement the contractors will be left with two alternatives: the first one is to wash and combine the aggregates to get an aggregate of acceptable quality and the other alternative is to make a conservative design which is suitable for severe conditions. This might include use of OPC in place of PPC, increasing the amount of cement and so on. However, both alternsatives result in an additional cost to the Contractor.

With respect to standardization of concrete making materials, the requirements set in the Ethiopian standard are not sufficient enough and also the quality requirements of contract documents and work supervisors in construction projects are quite loose. However, the situation in Germany is quite different. Almost all the materials used in the construction industry are standardized and also the procedure that should be followed to produce these materials is also stated in their standard. In addition, responsible authorities and construction supervisors make all the necessary check up on the quality of the materials.

The other important aspect with respect to production process of aggregates is environmental impact of aggregate production plant. This research has shown that the aggregate production plants in Addis Ababa have significant impact in their surrounding environment. In addition the effort that responsible statutory bodies are making towards controlling the production plants with respect to environmental impact is too minimal. However, the situation in Germany is quite different, all parties involved in the production process take all the necessary precautions and measures to avoid the environmental impact of aggregate production plants.

As the results obtained in this research have shown, the introduction of ready- mixed concrete to the construction industry improves the current problem of concrete producers failing to produce concrete which satisfies requirements. In addition, the use of ready mix concrete would improve the quality of concrete produced and help towards the proper utilization of naturally available raw materials.

7. RECOMMENDATIONS

FINE AGGREGATES

1. Fine aggregate producers should be organized to produce fine aggregate which, in addition to its consistency, satisfies standard requirements.
2. The sand production method should employ modern technologies. Utilization of machineries like loaders and excavators in place of primitive labor based production should also be taken in to consideration. Screening plants should be established where fine aggregates are being produced especially in places where the quarry sites are relatively suitable for such plants and in places where the quarry plant is accessible to the nearby highway.
3. Responsible statutory bodies should impose standardization requirements on parties who are producing fine aggregates.

COARSE AGGREGATES

1. Thorough study before selection quarry sites should be given due emphasis.
2. Close control of the production process.
3. Site location and selection is very important.

GEOLOGICAL ASPECTS

1. Geological engineering map of Ethiopia is very important to the proper utilization of the construction raw materials in Ethiopia.
2. General in – depth investigation like general evaluation on petrography of rocks to assure quality against reactivity of aggregates is important. Close investigation of geological properties would be easy if Engineers and Geologists work together.
3. Identification of alternative sites and incorporating them in the future land use plan should also be considered.

ENVIRONMENTAL IMPACT ASPECTS

1. Creating awareness that quarry sites with in the city and among settlements could be detrimental to people's well being and health and hence to look for other areas that could not cause much harm.
2. If there is environmental, social impact on the surrounding area, technical advice should be given to enable limitation of number of bore holes, stripping lines and extent of depth, amount of explosive material use etc. to make the development environmentally friendly.

3. Ensuring that the quarrying activity would not adversely affect the environment and society through precluding sustainable urban development.
4. Take urgent appropriate legal actions to safeguard the environment from inappropriate land management.

STANDARDIZATION AND RESEARCH ASPECTS

1. Laboratories should check all qualities of aggregates to investigate their compliance to standards.
2. Quarry sites should be checked for standards. They should have consistent quality and quality assurance periodically. The customer should be able to compare quality of the aggregate with out any expenses for tests.
3. Laboratory tests should be compiled periodically for further research works.

CONCRETE PRODUCTION ASPECTS

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

REGULATIONS AND RESPONSIBILITIES OF STATUTORY ORGANS

1. Putting stringent quality criteria with respect to the production of coarse and fine aggregates.
2. Based on the construction earth materials type, mining criteria and techniques, mining rules and regulations should be applied.
3. Assessement of new potental resources for fine and coarse aggregate sources to meet the increasing demand of these construction materials in Ethiopa.
4. The monitoring and follow-up mechanism of the responsible bodies should be improved.
5. In case of Addis Ababa, in order to keep the city structure development the Mines and Energy Department should be strengthened and its institutional capacity promoted to solve existing problems and ameliorate impacts.

CONTRACT DOCUMENTS PREPARATION AND SUPERVISON

Proper specifications should be prepared and proper control of the quality of aggregates should be carried out in construction projects.

8. SUGGESTIONS FOR FUTURE WORK

1. Advantages and disadvantages of using all-in aggregates in place of single sized aggregates for concrete production.
2. The potential of alkali-aggregate reaction of concrete produced in Ethiopia.
3. Percentage of wastage of concrete and concrete making materials in the Ethiopian Construction Industry.
4. Actual supply and demand gap of concrete making materials in the Ethiopian Construction Industry.
5. Assesssment of suitability of the different types of rocks that are available in Ethiopia for production of concrete.
6. Prospects of using ready-mixed concrete in the Ethiopian Construction Industry.

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ANNEXES

ANNEX A

A1 Source and Designation of fine aggregate samples

Designation	Source	Test date	Remark (Specific Source)
F1	Around A.A.	19.10.04	Meja Shenen
F2	Around A.A.	19.10.04	Batu Degaga
F3	Around A.A.	19.10.04	Batu Degaga
F4	Around A.A.	19.10.04	Dire Degaga
F5	Around A.A.	19.10.04	Melka Gerbi
F6	Around A.A.	19.10.04	Oda Bekota (Meki)
F7	Around A.A.	19.10.04	Chele Kiltu
F8	Around A.A.	19.10.04	Meti Sembo
F9	Around A.A.	19.10.04	Shalenge
F10	Around A.A.	16.01.05	Dera
F11	Alemaya	30.3.05	Alemaya
F12	Mekele	10.4.05	Giba
F13	Mekele	10.4.05	Giba
F14	North east Ethiopia	7.01.05	Mille
F15	North West Ethiopia	22.12.04	Nekempte
F16	Nathareth-Assela	3.12.04	Mermersa
F17	Nathareth-Assela	3.12.04	Sodere
F18	Around A.A.	15.3.05	Kality
F19	Around A.A.	15.3.05	Kality
F20	Around A.A.	14.4.05	Addis Ababa
F21	Around A.A.	12.01.05	Addis Ababa
F22	Around A.A.	3.02.05	Addis Ababa
F23	Around A.A.	4.02.05	Addis Ababa
F24	Around A.A.	15.3.05	Addis Ababa
F25	Around A.A.	15.01.05	Addis Ababa
F26	Around A.A.	28.3.05	Addis Ababa
F27	Around A.A.	17.9.04	Addis Ababa
F28	Around A.A.	26.01.05	Addis Ababa
F29	Around A.A.	1.03.05	Addis Ababa
F30	Around A.A.	22.02.05	Addis Ababa
F31	Around A.A.	28.02.05	Addis Ababa
F32	Around A.A.	15.01.05	Addis Ababa
F33	Around A.A.	24.02.05	Addis Ababa
F34	Around A.A.	13.5.05	Addis Ababa
F35	Around A.A.	28.02.05	Addis Ababa
F36	Around A.A.	21.02.05	Addis Ababa
F37	Around A.A.	22.02.05	Addis Ababa
F38	Around A.A.	17.3.05	Addis Ababa
F39	North Shoa	8.4.05	Mida Metala
F40	Around A.A.	25.4.05	Addis Ababa
F41	Dire Dawa	22.02.05	-
F42	Around A.A.	24.3.05	Addis Ababa
F43	Around A.A.	24.3.05	Addis Ababa
F44	Around A.A.	24.3.05	Meki
F45	Around A.A.	30.3.05	Addis Ababa
F46	n/a	n/a	n/a
F47	n/a	n/a	n/a

A2 Sources and Designation of coarse aggregate samples

Designation	Source	Date of testing	Specific Source	Nominal Agg. SIze
C1	Dera	16.01.05	Dera	37-5
C2	Alemaya	30.3.05	Alemaya	37-5
C3	Mekele	10.4.05	Misham	37-5
C4	Mekele	10.4.05	Dalul	37-5
C5	Mekele	10.4.05	Dalul	37-5
C6	Mekele	10.4.05	Derbi	37-5
C7	Around A.A.	16.9.05	Addis Ababa	19-5
C8	Around A.A.	16.9.05	Addis Ababa	19-5
C9	Around A.A.	14.12.05	n/a	37-5
C10	Nathareth-Assela	03.12.05	Blue Nile No1	19-5
C11	Nathareth-Assela	03.12.05	Blue Nile No2	19-5
C12	Around A.A.	15.3.05	Kality	13-5
C13	Around A.A.	15.3.05	Addis Ababa	37-5
C14	Bahar Dar	13.01.05	n/a	37-5
C15	Around A.A.	31.01.05	n/a	37-5
C16	Around A.A.	12.01.05	Addis Ababa	37-5
C17	Around A.A.	17.9.05	Addis Ababa	37-5
C18	Around A.A.	26.01.05	Addis Ababa	37-5
C19	Around A.A.	13.6.05	Addis Ababa	13-5
C20	Around A.A.	13.6.05	Addis Ababa	19-5
C21	Around A.A.	13.6.05	Addis Ababa	37-5
C22	Around A.A.	28.02.05	Addis Ababa	37-5
C23	Around A.A.	-	Addis Ababa	37-5
C24	Around A.A.	21.02.05	Addis Ababa	37-5
C25	Around A.A.	22.02.05	Addis Ababa	37-5
C26	Around A.A.	17.3.05	Akaki Kality	13-5
C27	Around A.A.	25.4.05	Addis Ababa	37-5
C28	Dire Dawa	22.02.05	-	13-5
C29	Dire Dawa	22.02.05	-	19-5
C30	Around A.A.	-	Addis Ababa	19-5
C31	Around A.A.	24.3.05	Addis Ababa	37-5
C32	Around A.A.	22.3.05	Addis Ababa	37-5
C33	n/a	n/a	n/a	37-5
C34	n/a	n/a	n/a	37-5
C35	n/a	n/a	n/a	13-5
C36	n/a	n/a	n/a	13-5
C37	Around A.A.	16.01.05	Addis Ababa	37-5

A3 Sources and Designation of the rock samples

Designation	Source	Date of testing	Particular Source Location
R1	Wollo	17.12.04	Kesem
R2	A.A	24.3.05	-
R3	Gojam	16.3.05	Chemoga - Yedo
R4	Gojam	16.3.05	Getla

Annex B

B1 Sieve Analysis Result of fine aggregate Samples

Item No	Sample	Percentage Passing							Finness Modulus
		9.5[15]	4.75[15]	2.36[15]	1.18[15]	0.6[15]	0.3[15]	0.15[15]	
1	**F1**	100	97	86	53	12	5	2	3.45
2	**F2**	100	99	95	80	56	23	4	2.43
3	**F3**	100	98	95	85	55	28	13	2.26
4	**F4**	100	95	81	52	12	4	2	3.54
5	**F5**	100	100	100	100	69	17	4	2.10
6	**F6**	99	94	88	34	34	8	4	3.39
7	**F7**	98	94	82	60	23	10	6	3.27
8	**F8**	99	92	74	51	32	16	5	3.31
9	**F9**	98	96	92	82	24	6	5	2.97
10	**F10**	100	100	99	82	30	7	2	2.80
11	**F11**	98	95	83	57	21	9	4	3.33
12	**F12**	94	91	82	78	52	21	3	2.79
13	**F13**	98	97	96	93	70	23	3	2.20
14	**F14**	97	90	77	56	17	4	3	3.56
15	**F15**	-	-	-	-	-	-	-	-
16	**F16**	96	90	78	59	24	7	3	3.43
17	**F17**	99	97	92	76	31	10	5	2.90
18	**F18**	97	90	82	67	31	12	7	3.14
19	**F19**	100	99	93	78	52	29	8	2.41
20	**F20**	98	93	83	72	34	10	4	3.06
21	**F21**	99	96	89	76	42	16	7	2.75
22	**F22**	89	80	68	53	27	15	9	3.59
23	**F23**	98	95	87	72	32	9	5	3.02
24	**F24**	99	96	89	82	51	20	7	2.56
25	**F25**	99	96	90	77	38	14	7	2.79
26	**F26**	100	100	71	43	21	12	8	3.45
27	**F27**	100	96	92	85	51	19	8	2.49
28	**F28**	99	97	90	82	48	18	7	2.59
29	**F29**	92	82	62	43	19	7	4	3.91
30	**F30**	97	89	71	43	14	7	5	3.75
31	**F31**	99	95	90	75	33	13	6	2.89
32	**F32**	98	95	88	68	27	7	1	3.16
33	**F33**	96	90	82	60	20	5	3	3.44
34	**F34**	99	96	88	73	39	14	6	2.85
35	**F35**	100	98	88	63	23	8	5	3.15
36	**F36**	96	93	89	82	59	30	10	2.41
37	**F37**	100	96	84	60	31	23	6	3.00
38	**F38**	99	90	79	65	21	10	6	3.30
39	**F39**	100	96	88	73	42	21	7	2.73
40	**F40**	98	94	85	64	23	7	3	3.26
41	**F41**	96	91	85	74	43	15	4	2.92
42	**F42**	99	97	92	64	31	15	6	2.96
43	**F43**	98	95	88	75	43	16	7	2.78
44	**F44**	99	98	95	88	55	11	4	2.50
45	**F45**	98	95	91	83	58	28	15	2.32
46	**F46**	100	99	97	96	72	21	2	2.14
47	**F47**	99	96	88	62	32	12	4	3.08
ES requirement		100	95-100	80-100	50-85	25-60	10-30	2-10	2.0 – 3.5

[15] Sieve sizes in mm

B2 Sieve Analysis Result of the coarse aggregate Samples 37-5 Nominal Aggregate Size

Item No	Sample	Sieve Sizes and Percentage Passing					
		75•	37,5•	19•	9,5•	4,75•	Fineness Modulus
1	C1	100	100	81	32	4	6.83
2	C2	100	100	49	3	1	7.47
3	C3	100	100	67	1	0	7.32
4	C4	100	100	71	2	0	7.27
5	C5	100	100	49	3	1	7.17
6	C6	100	100	66	15	4	7.15
7	C9	100	98	30	3	0	7.69
8	C13	100	100	48	10	1	7.41
9	C15	100	100	53	7	0	7.40
10	C16	100	100	51	7	1	7.41
11	C17	100	100	30	3	0	7.67
12	C18	100	100	72	11	1	7.16
13	C21	100	100	41	8	0	7.51
14	C22	100	100	62	11	1	7.26
15	C23	100	100	78	9	1	7.12
16	C24	100	100	45	3	0	7.52
17	C25	100	100	47	13	5	7.35
18	C27	100	100	62	10	2	7.26
19	C31	100	100	84	-	-	7.13
20	C32	100	100	70	-	-	7.26
21	C33	100	100	47	6	0	7.43
21	C34	100	100	54	3	0	7.40
The ES requirement		100	95-100	30-70	10-35	0-5	5.5-8.5

B3 Sieve Analysis Result of the coarse aggregate Samples 19-5 Nominal Aggregate Size

Item No	Sample	Sieve Sizes and Percentage Passing						Fineness Modulus
		37,5•	25•	19•	12,5•	9,5•	4,75•	
1	C7	100	100	82	28	7	0	7.11
2	C8	100	100	98	83	16	0	6.86
3	C10	100	100	73	40	23	7	6.97
4	C11	100	100	87	59	36	11	6.66
5	C20	100	100	90	51	27	3	6.18
6	C29	100	100	86	32	6	0	6.62
7	C30	100	100	91	33	9	1	6.57
The ES requirement		100	-	95-100	-	25-55	0-10	5.5-8.5

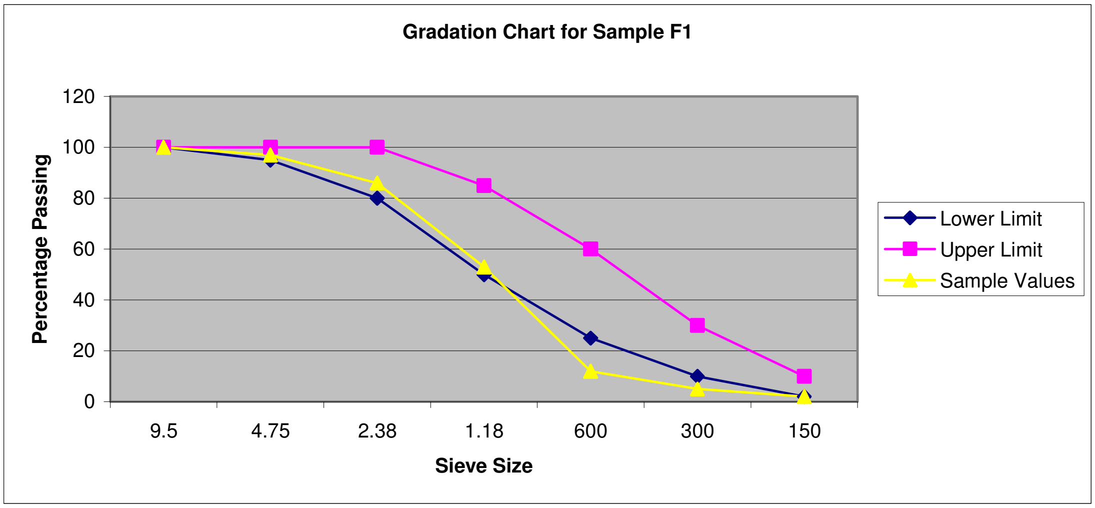
B4 Sieve Analysis Result of the coarse aggregate Samples 13-5 Nominal Aggregate Size

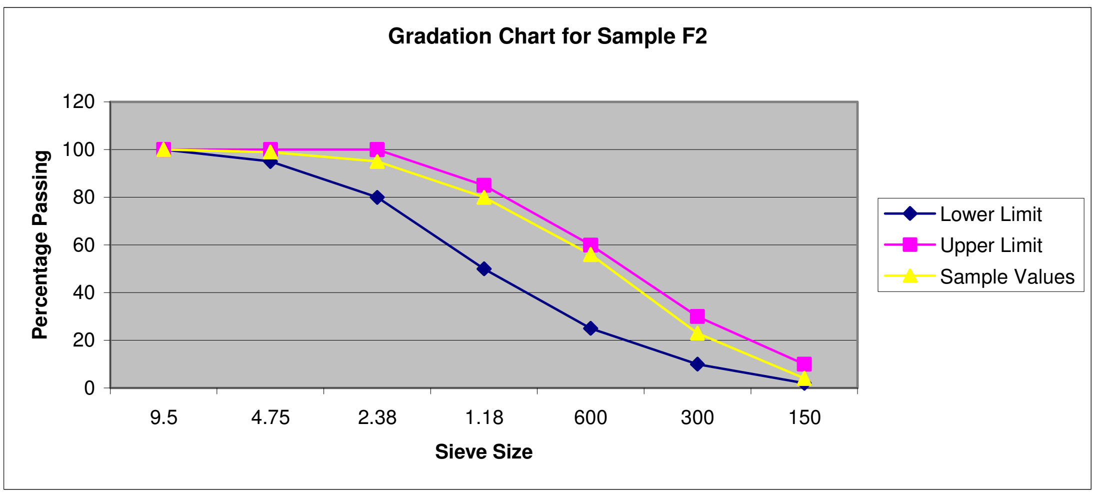
Item No	Sample	Sieve Sizes and Percentage Passing				Fineness Modulus
		19•	12,5•	9,5•	4,75•	
1	C12	100	100	99	27	5.70
2	C19	100	100	100	37	5.59
3	C26	100	100	99	19	5.76
4	C28	100	99	87	9	6.05
5	C35	100	100	99.5	95.2	4.34
6	C36	100	100	100	94.9	4.71
The ES requirement		100	90-100	40-85	0-10	5.5-8.5

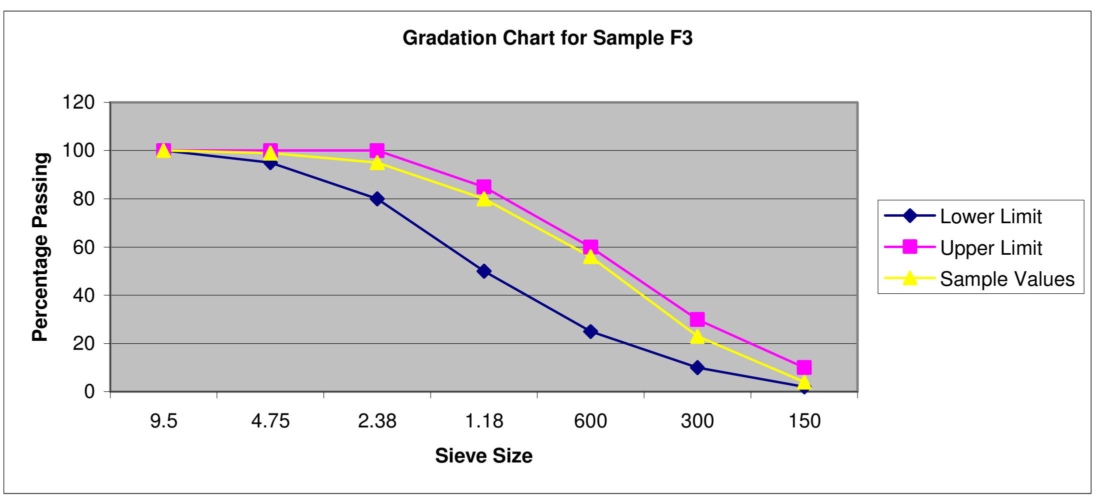
• Sieve sizes in mm

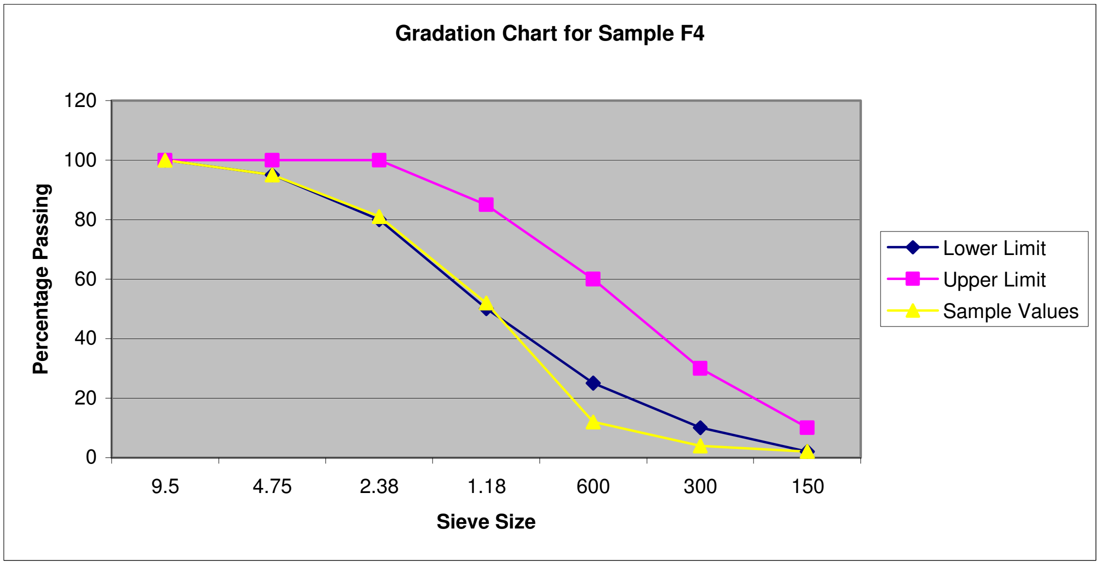
Annex C Gradation Charts of the collected samples

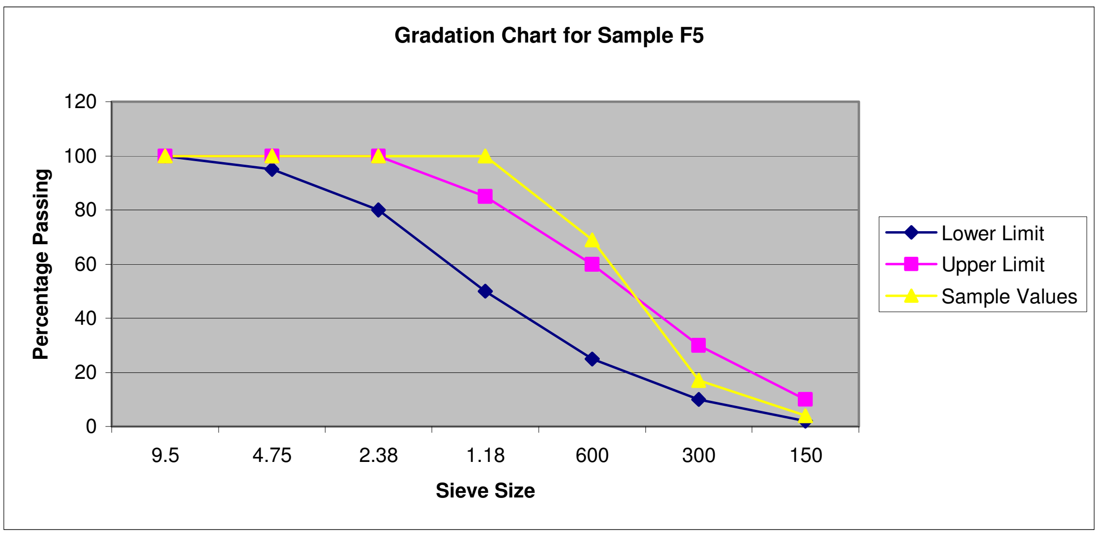
C1 Fine Aggregates

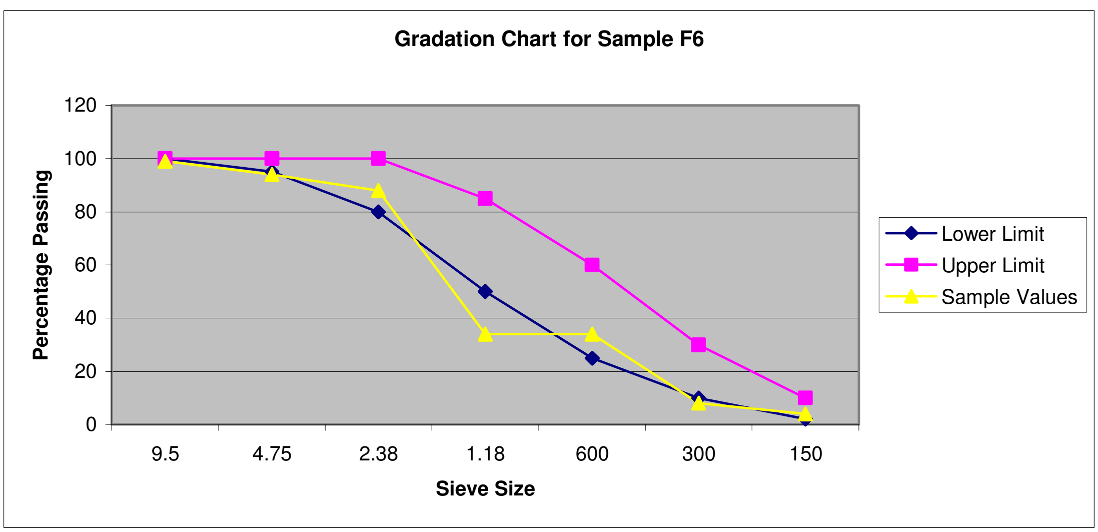


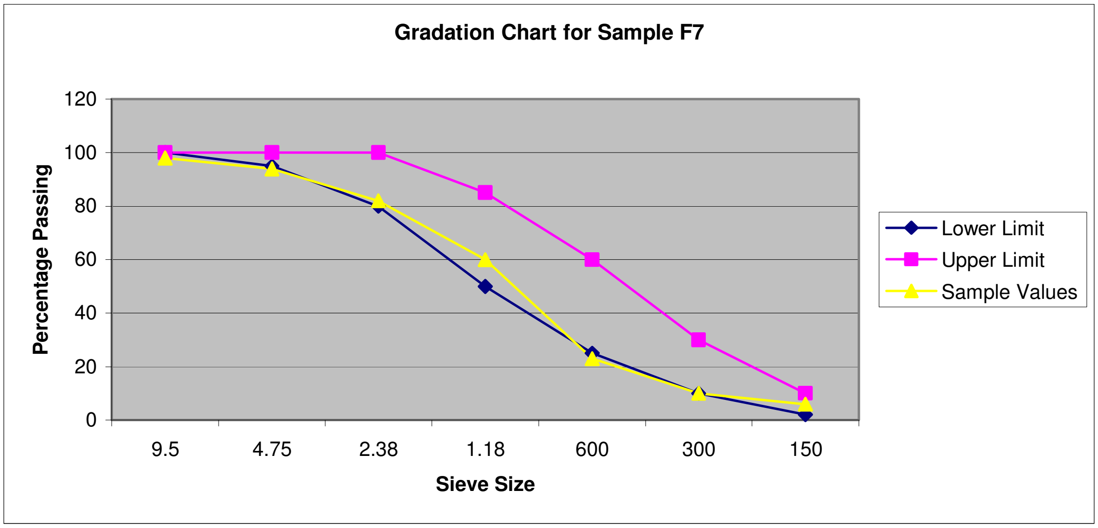


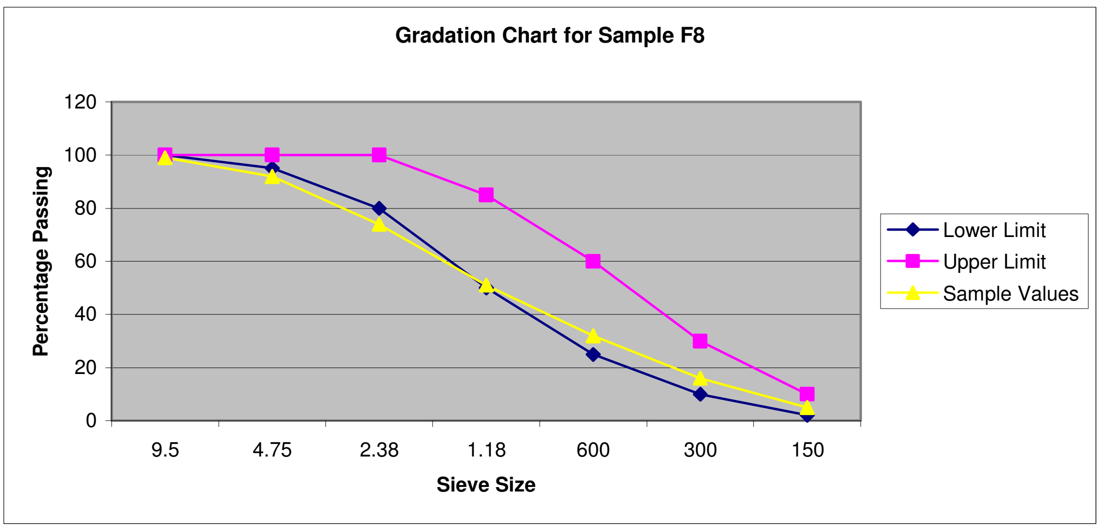


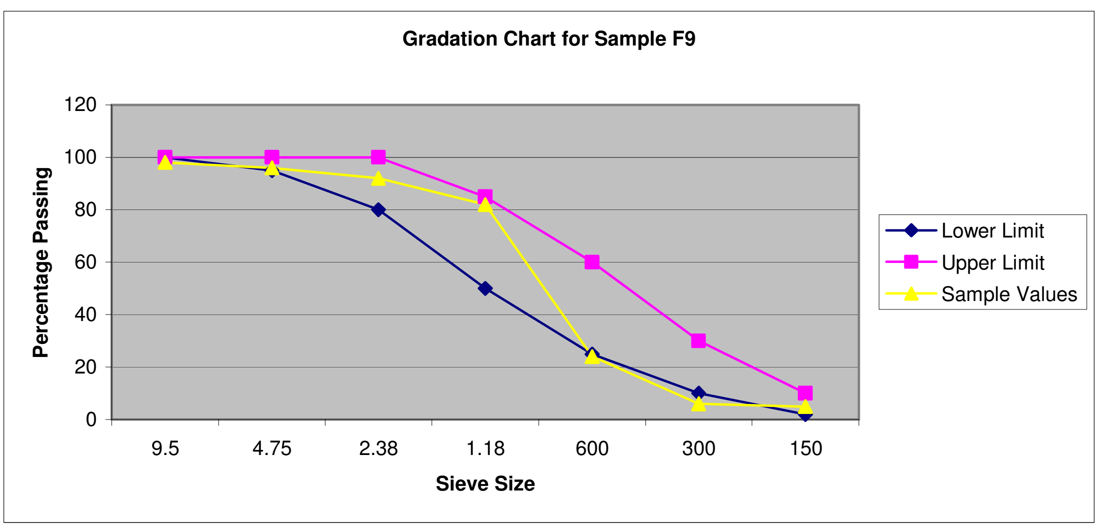

Gradation Chart for Sample F4
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

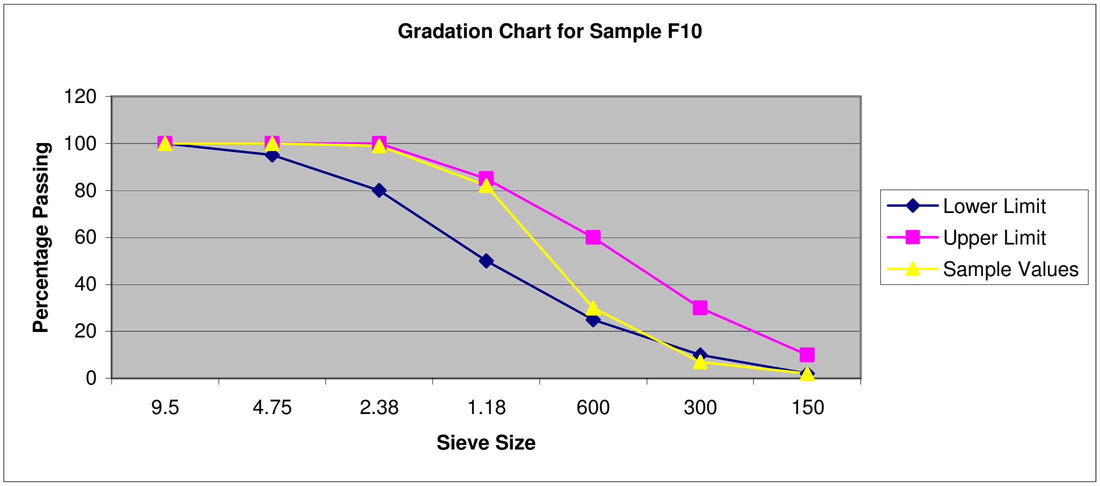

Gradation Chart for Sample F5
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

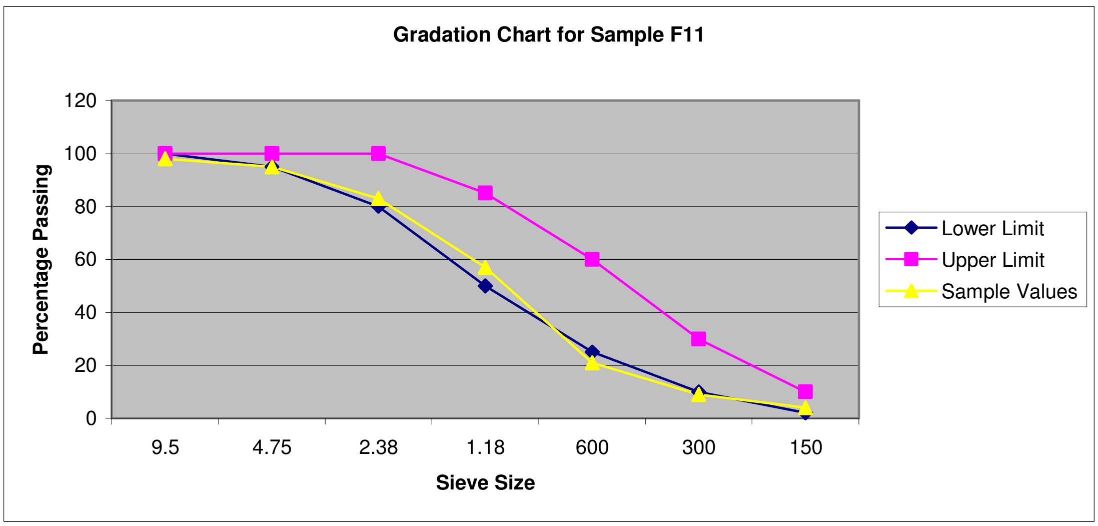

Gradation Chart for Sample F6
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

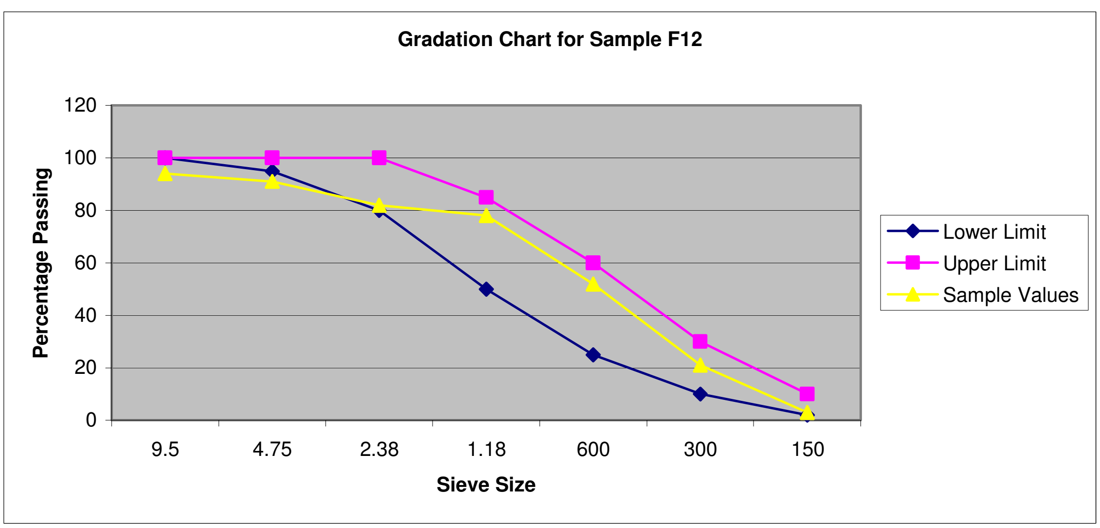

Gradation Chart for Sample F7
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

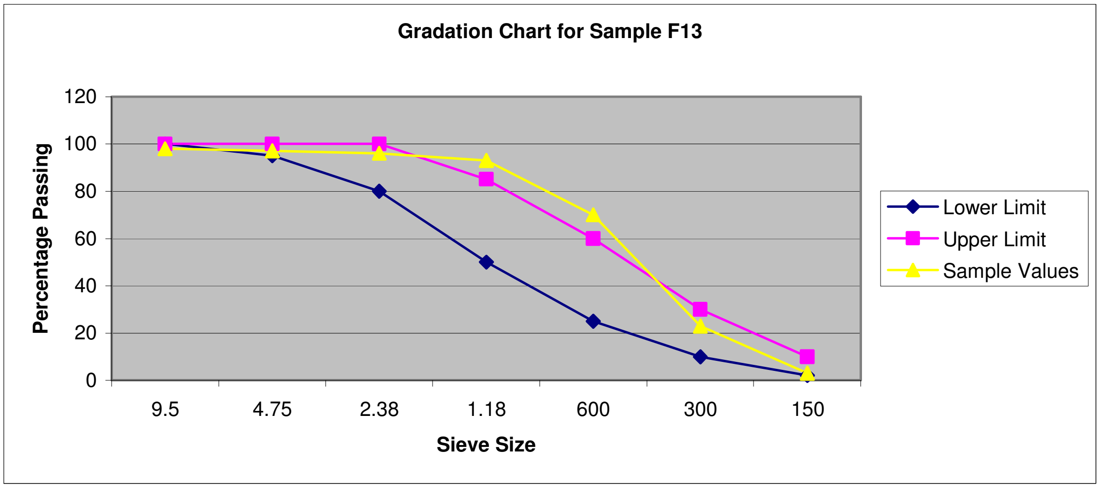

Gradation Chart for Sample F8
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

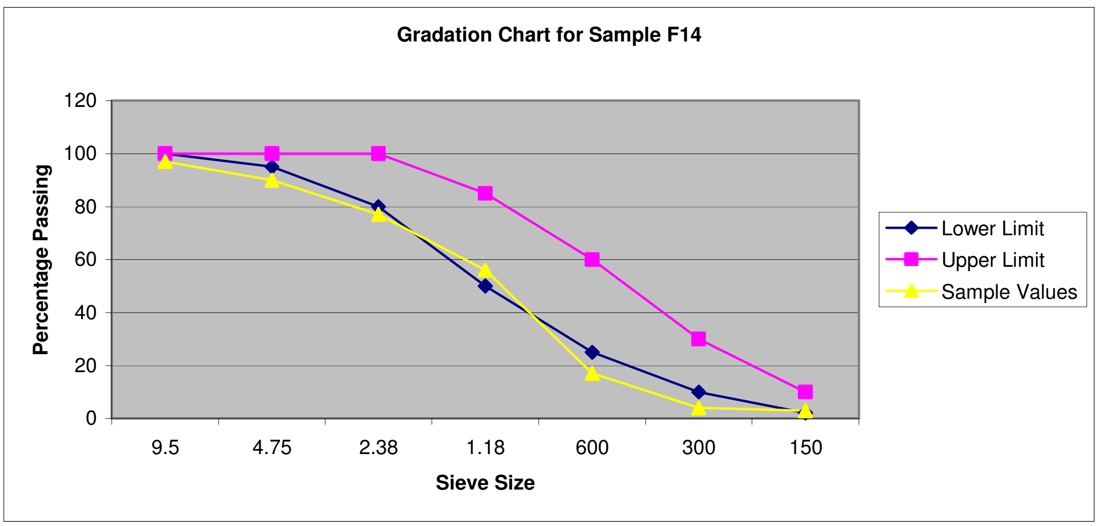

Gradation Chart for Sample F9
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

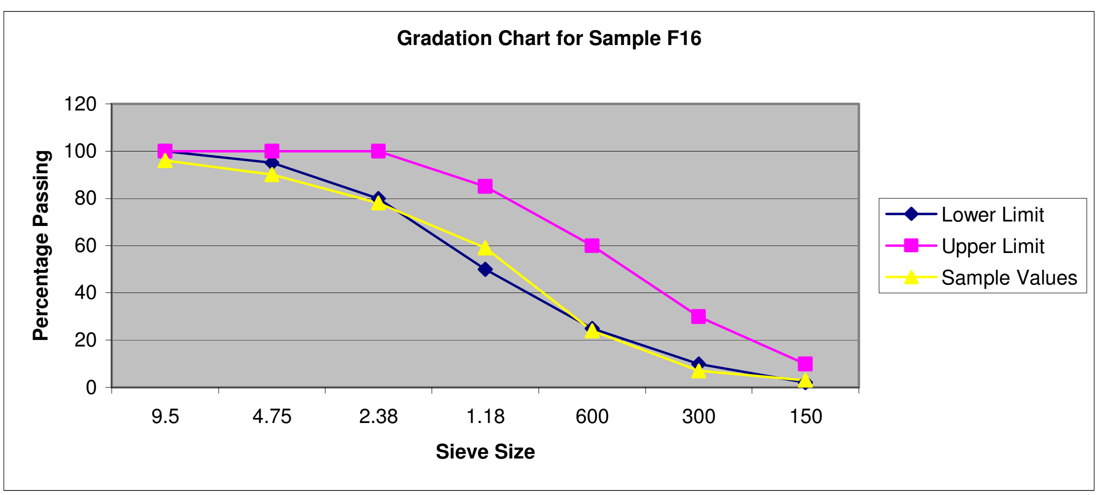

Gradation Chart for Sample F10
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

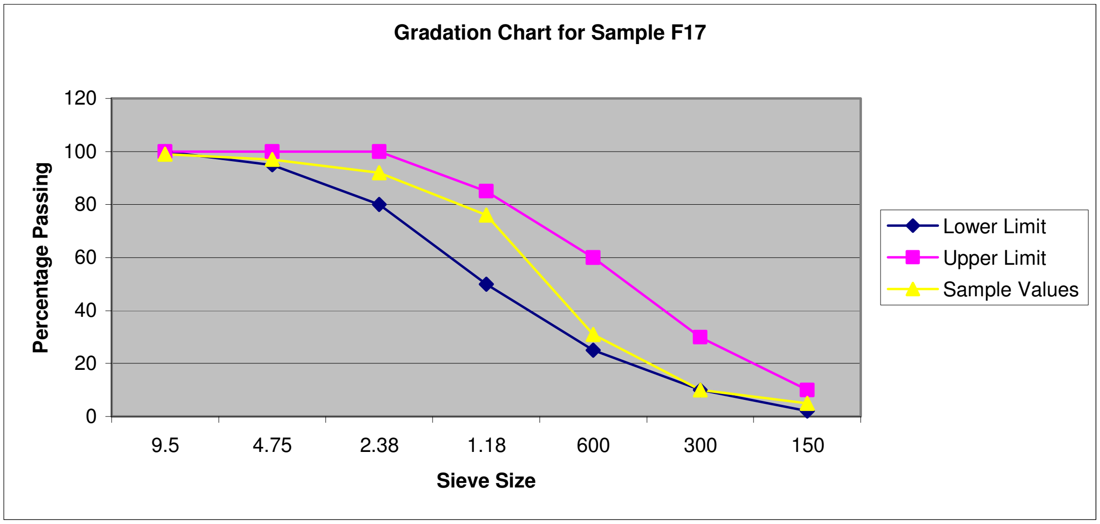

Gradation Chart for Sample F11
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

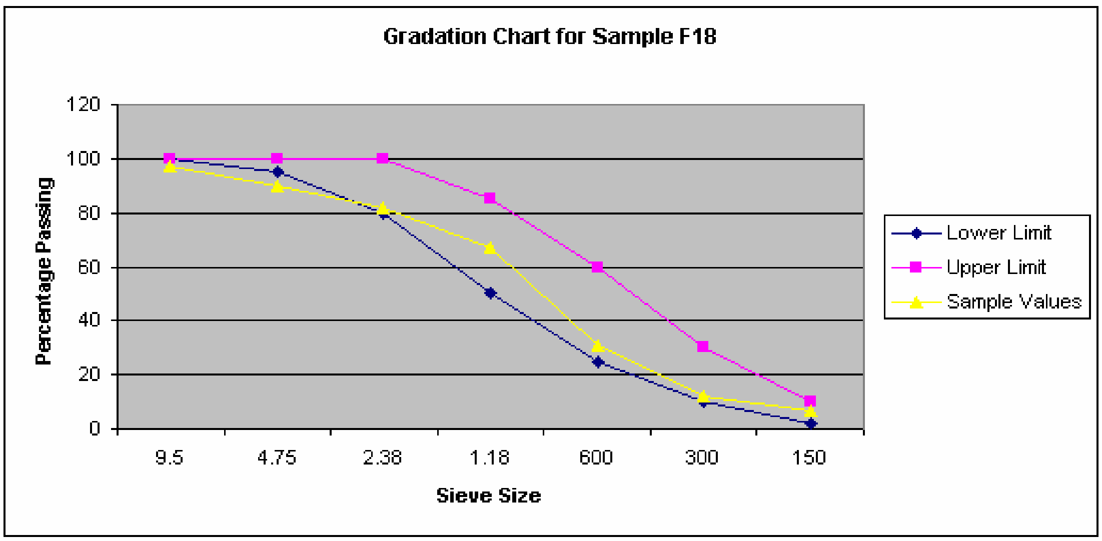

Gradation Chart for Sample F12
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

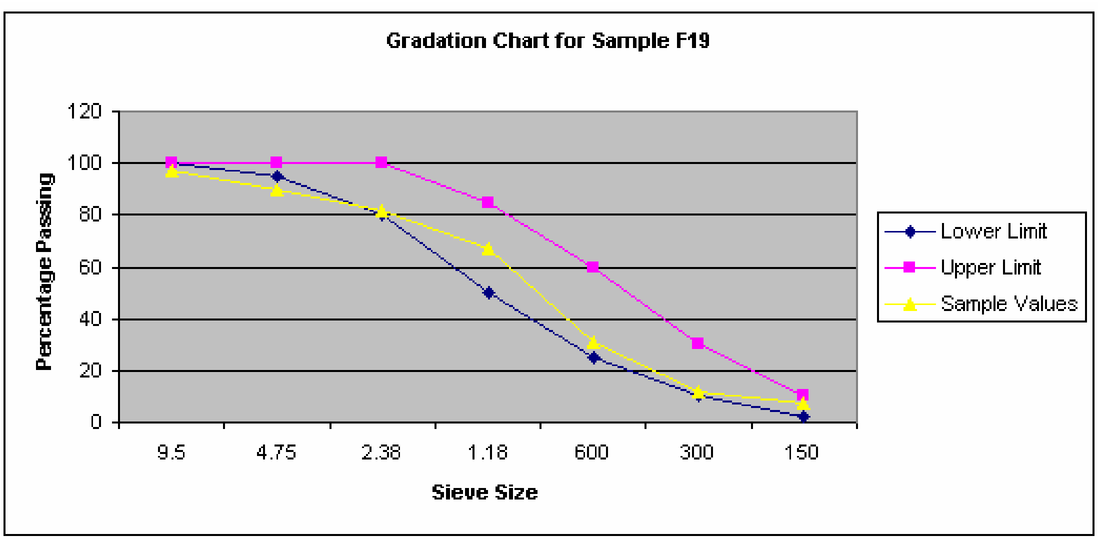

Gradation Chart for Sample F13
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

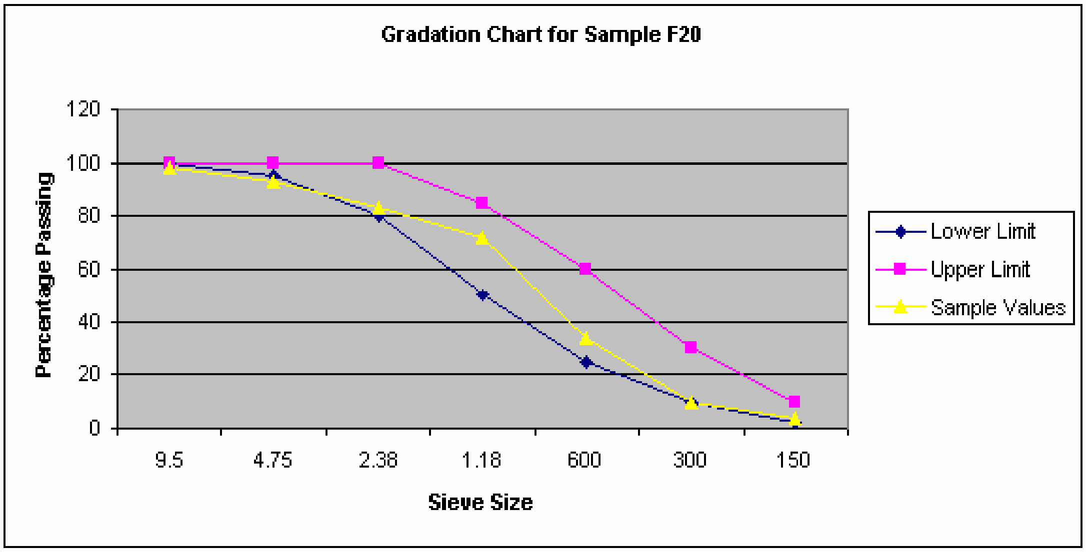

Gradation Chart for Sample F14
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values


Gradation Chart for Sample F16
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

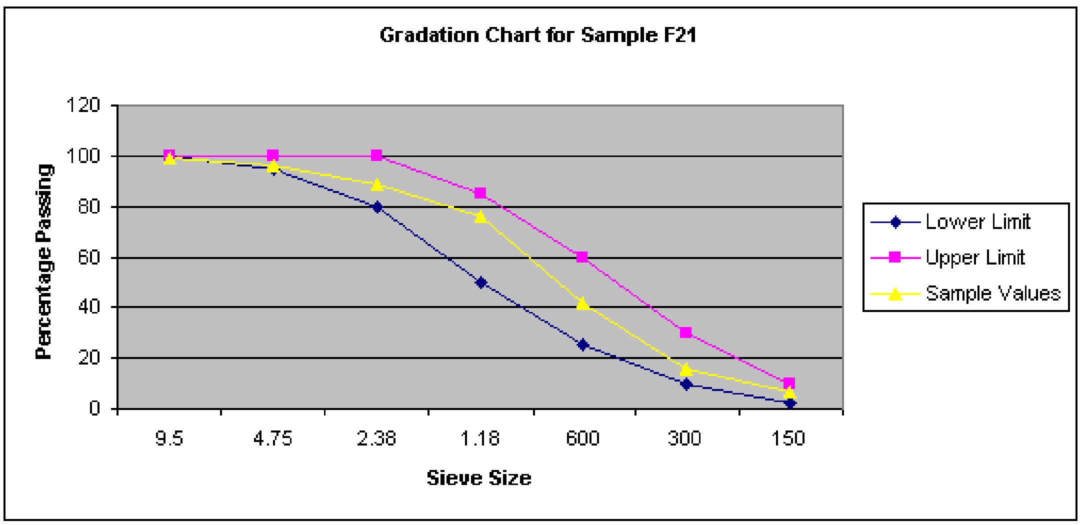

Gradation Chart for Sample F17
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values


Gradation Chart for Sample F18
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

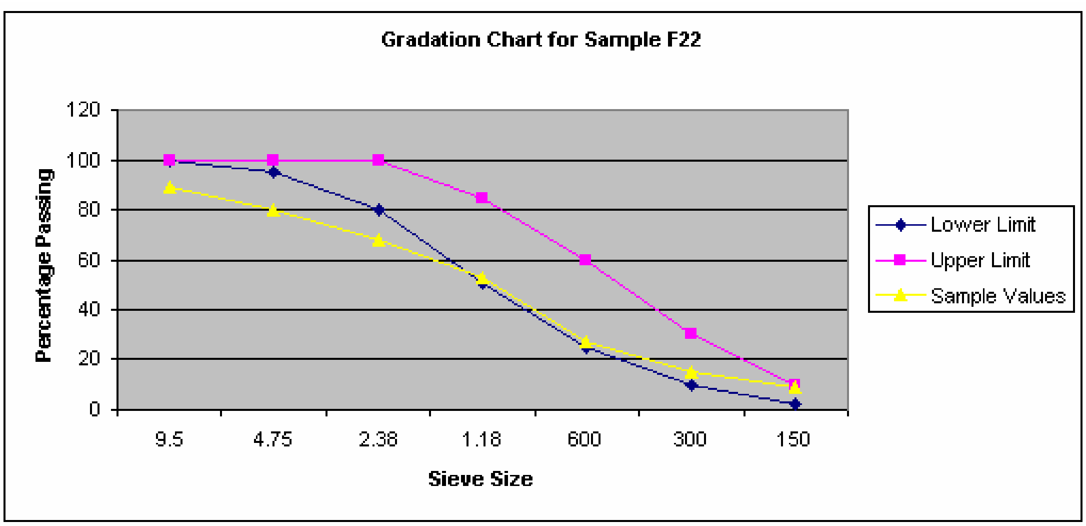

Gradation Chart for Sample F19
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values



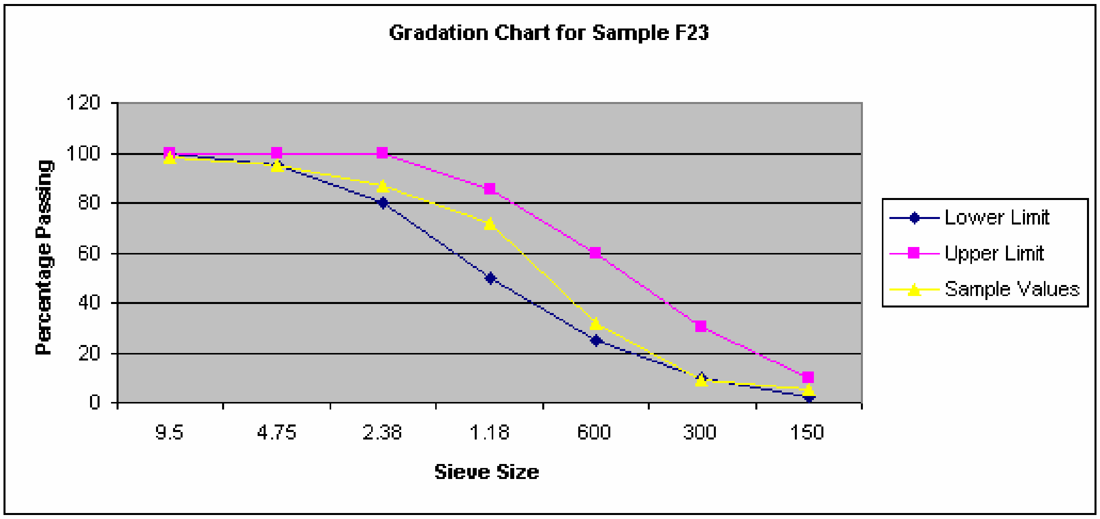
Gradation Chart for Sample F20
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

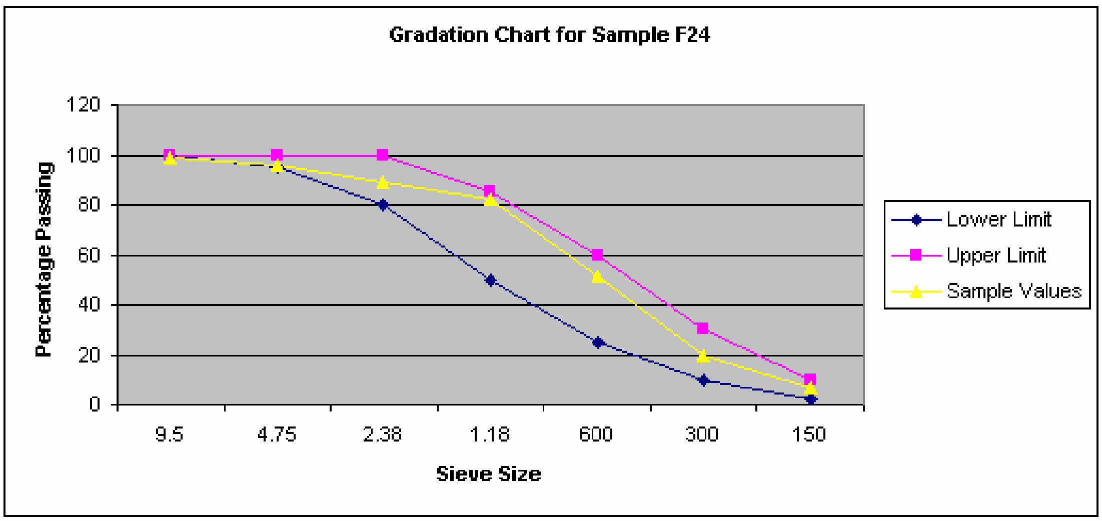


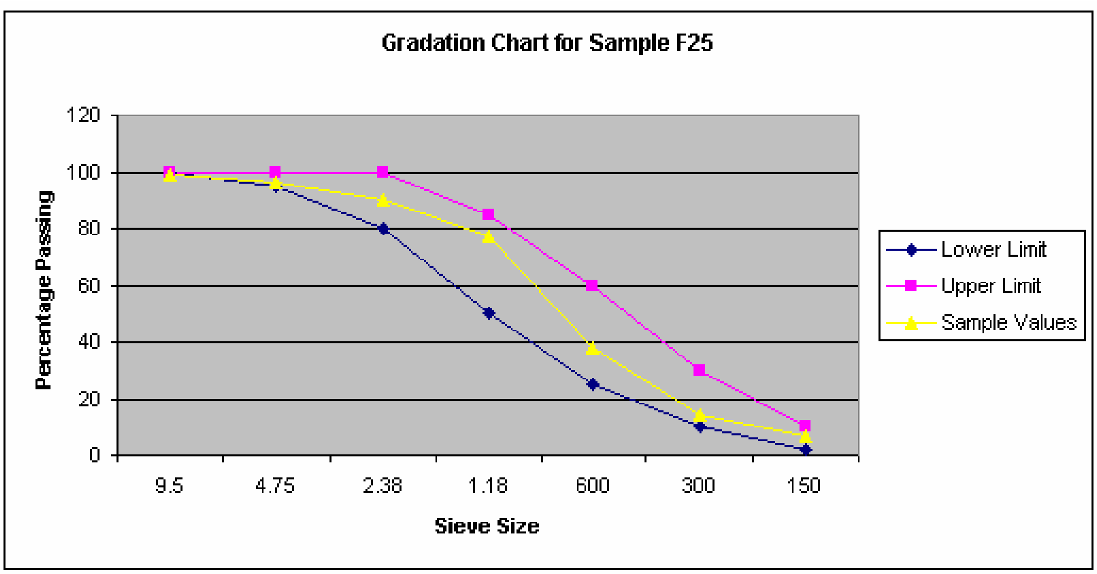
Gradation Chart for Sample F21
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

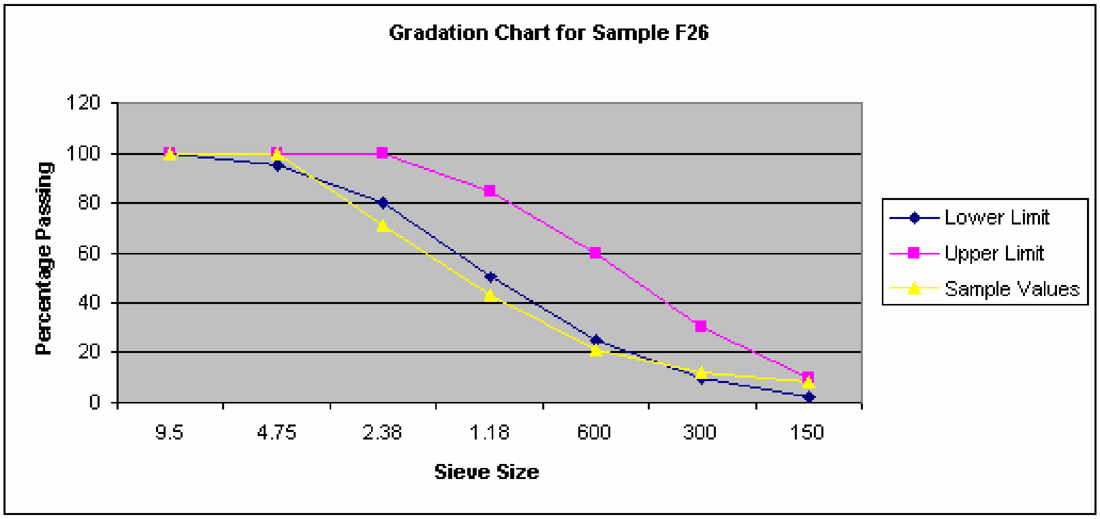


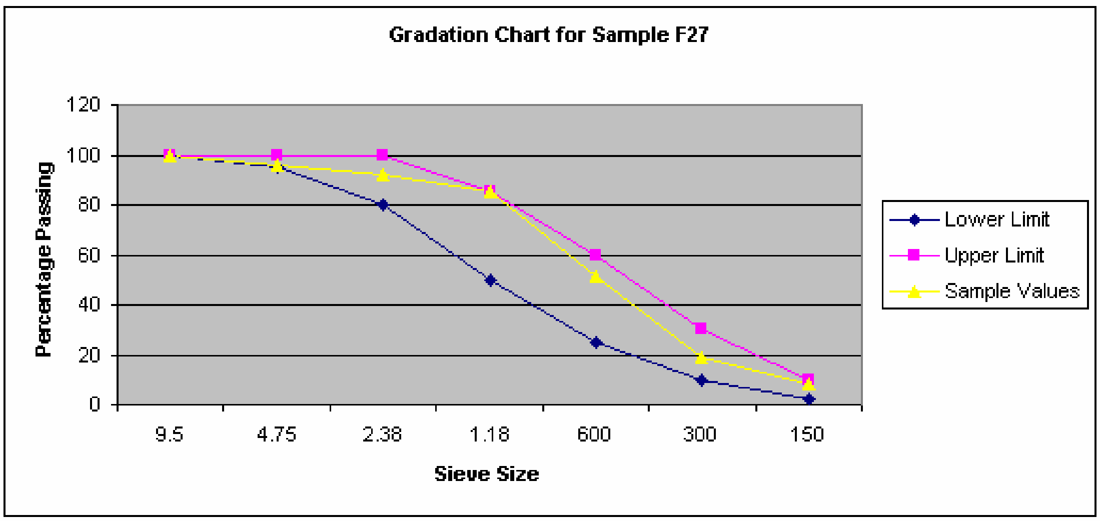
Gradation Chart for Sample F22
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

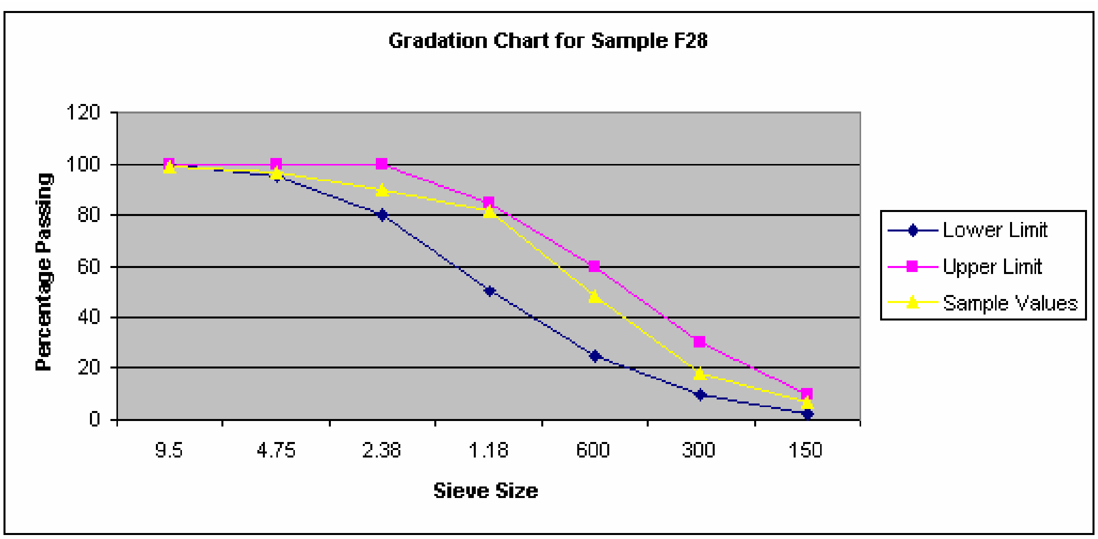

Gradation Chart for Sample F23
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

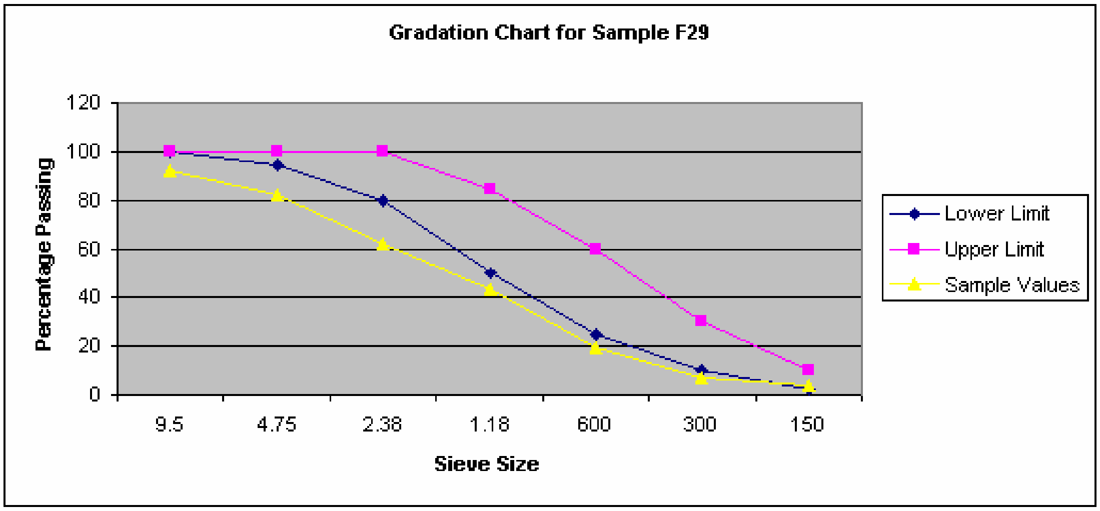

Gradation Chart for Sample F24
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

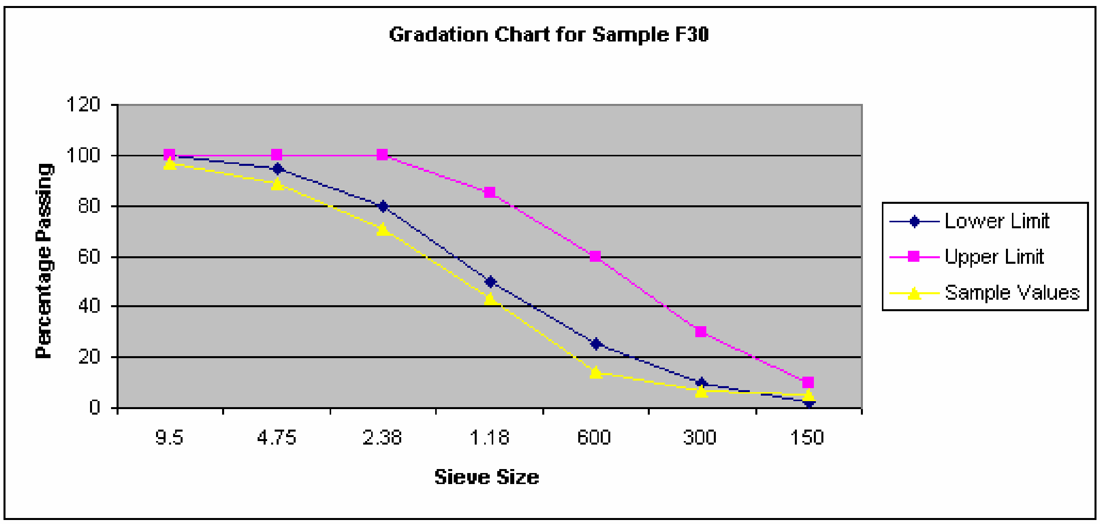

Gradation Chart for Sample F25
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

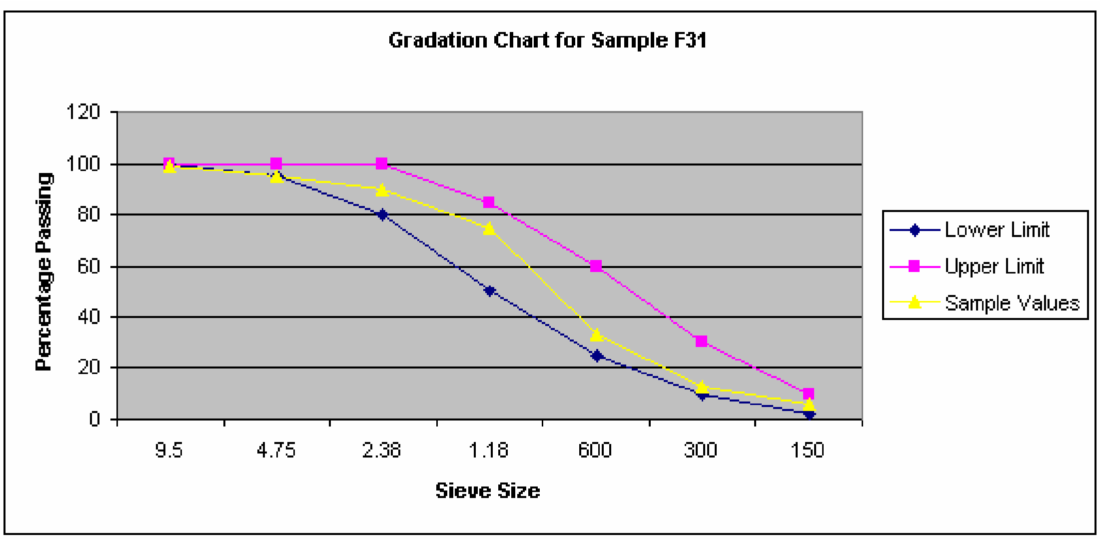

Gradation Chart for Sample F26
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

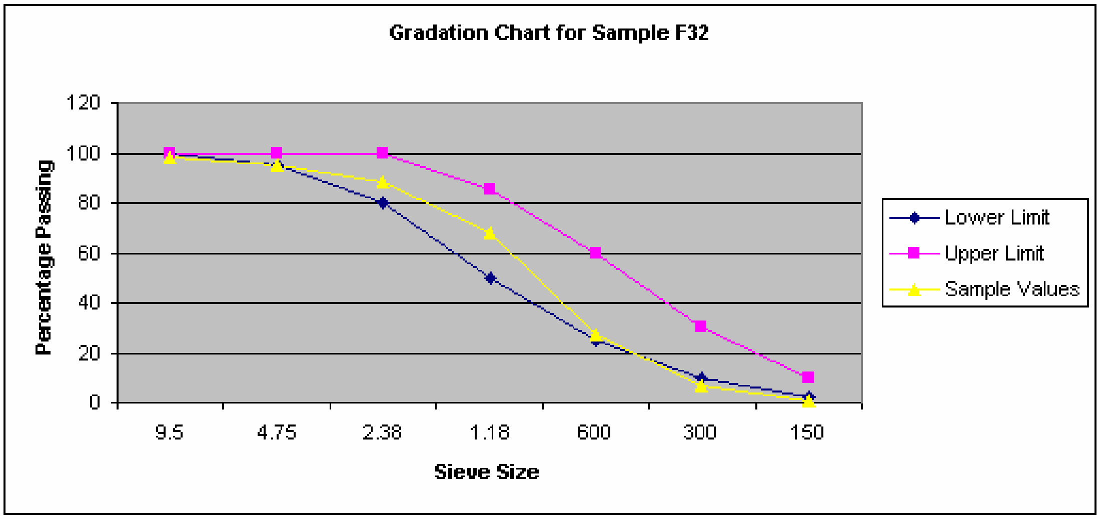

Gradation Chart for Sample F27
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

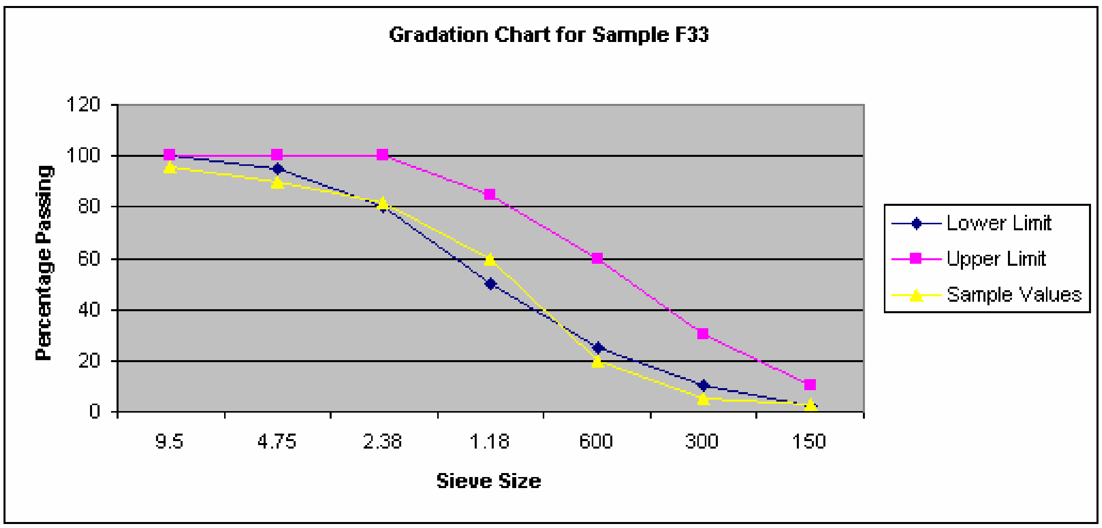

Gradation Chart for Sample F28
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

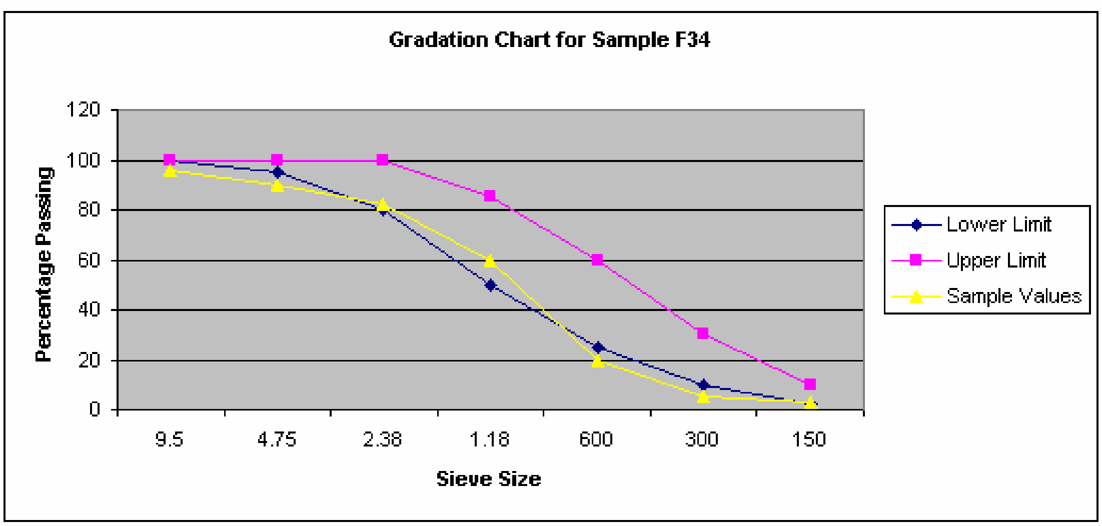

Gradation Chart for Sample F29
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

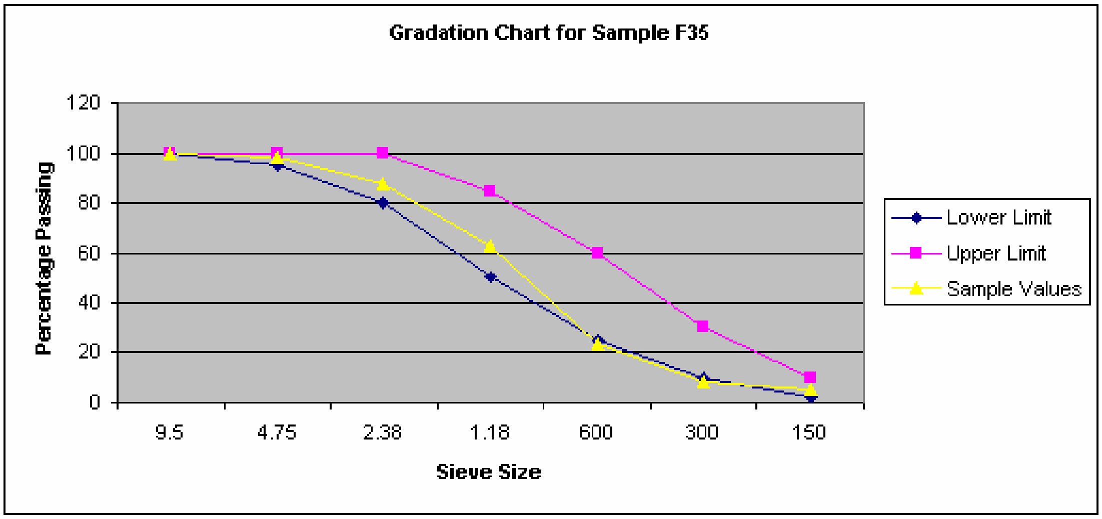

Gradation Chart for Sample F30
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

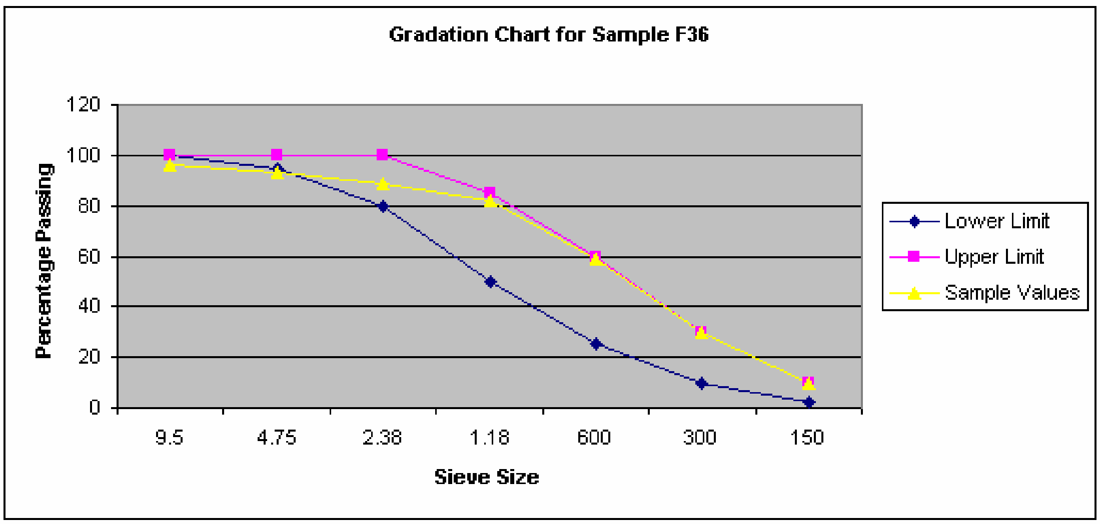

Gradation Chart for Sample F31
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

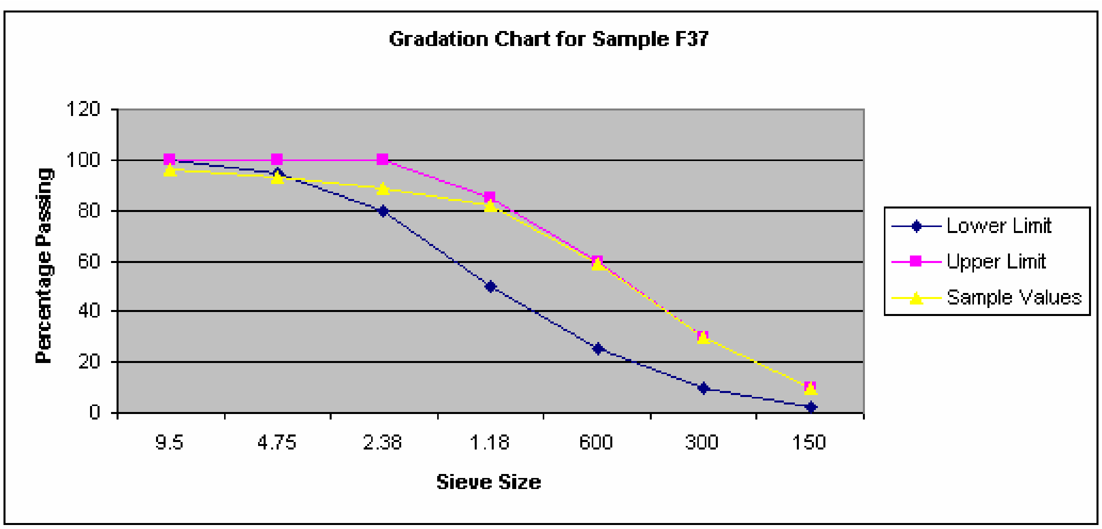

Gradation Chart for Sample F32
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

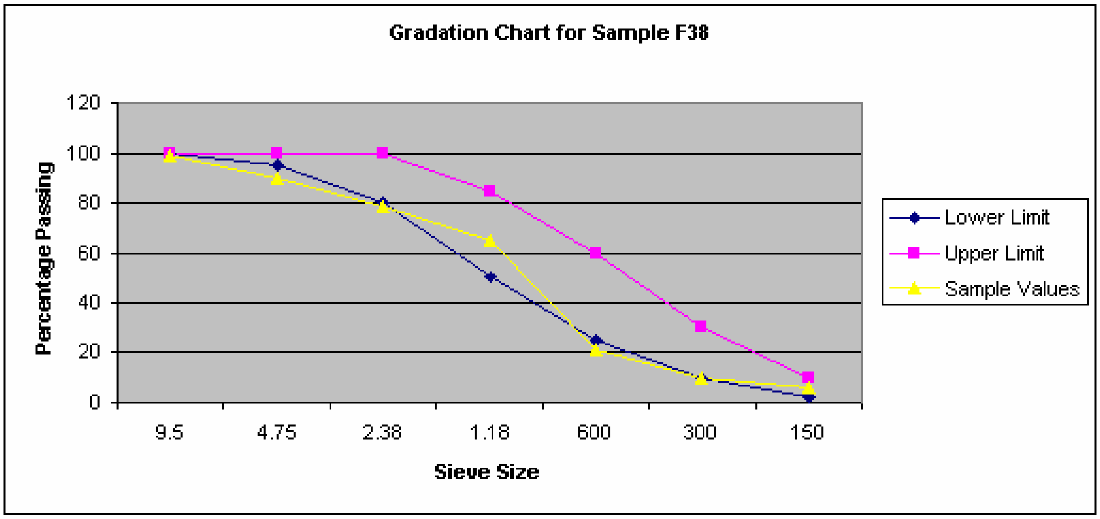

Gradation Chart for Sample F33
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

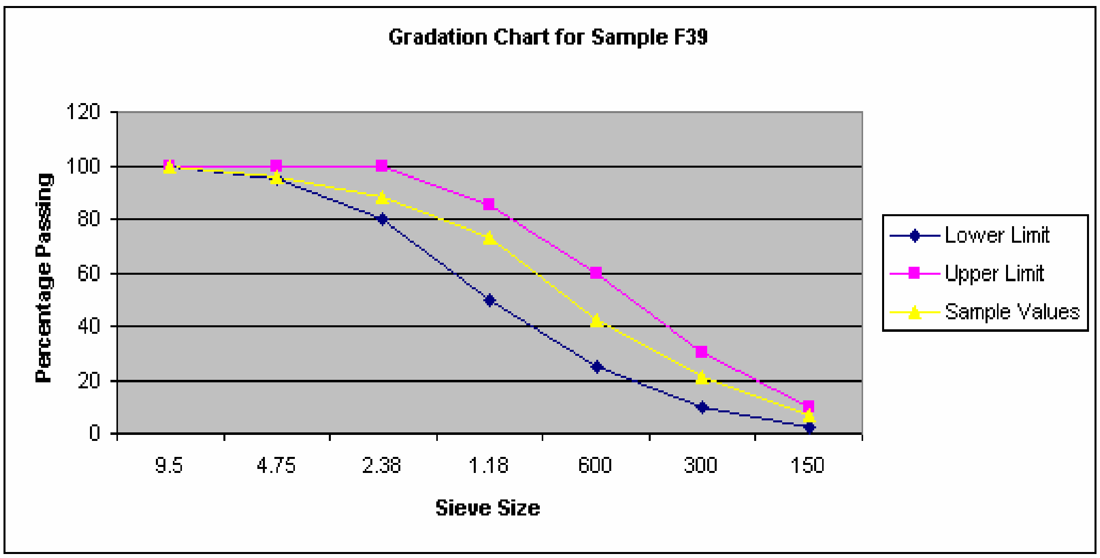

Gradation Chart for Sample F34
120
100
80
60
40
20
0
Percentage Passing
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

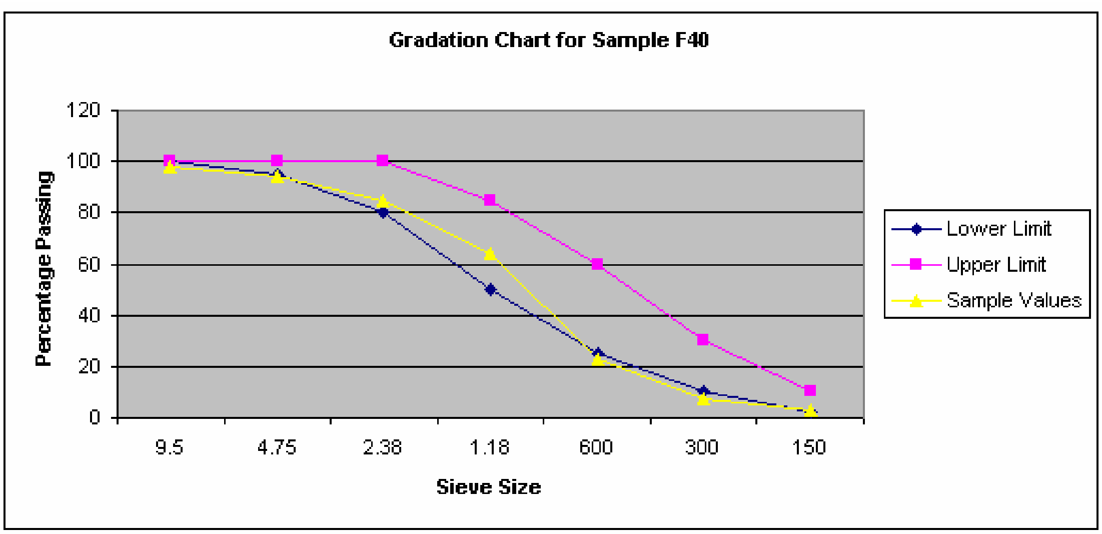

Gradation Chart for Sample F35
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

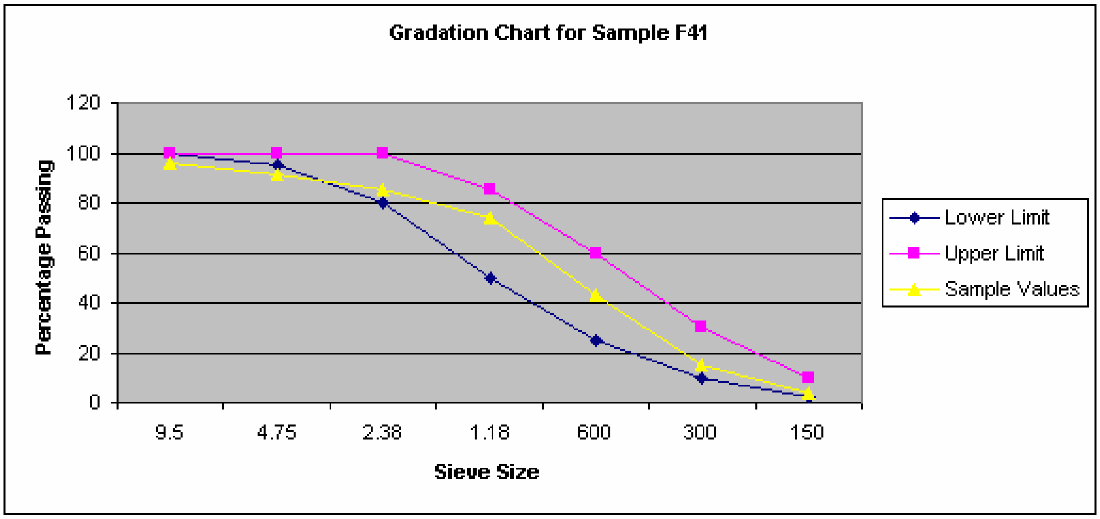

Gradation Chart for Sample F36
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values


Gradation Chart for Sample F37
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

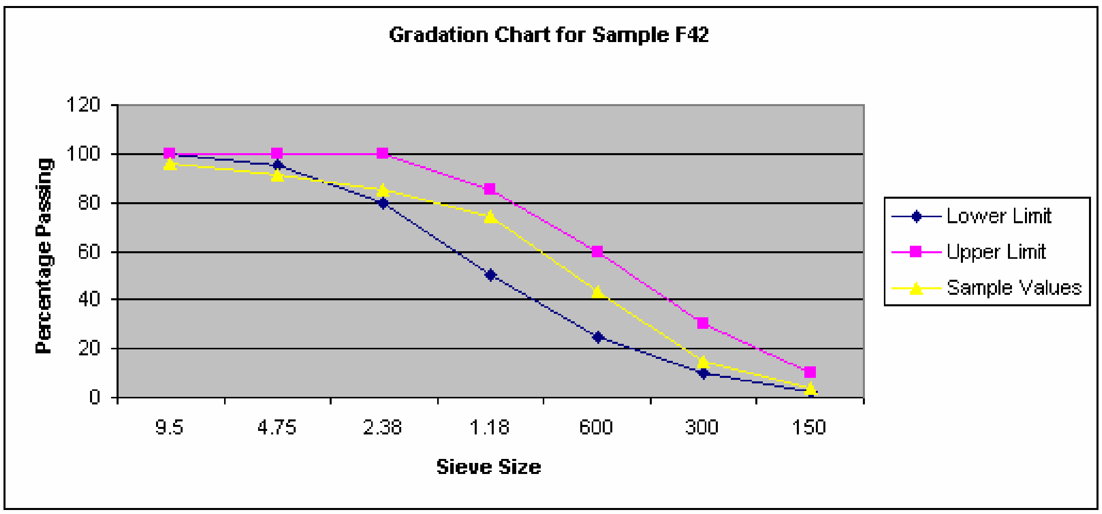

Gradation Chart for Sample F38
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values


Gradation Chart for Sample F39
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

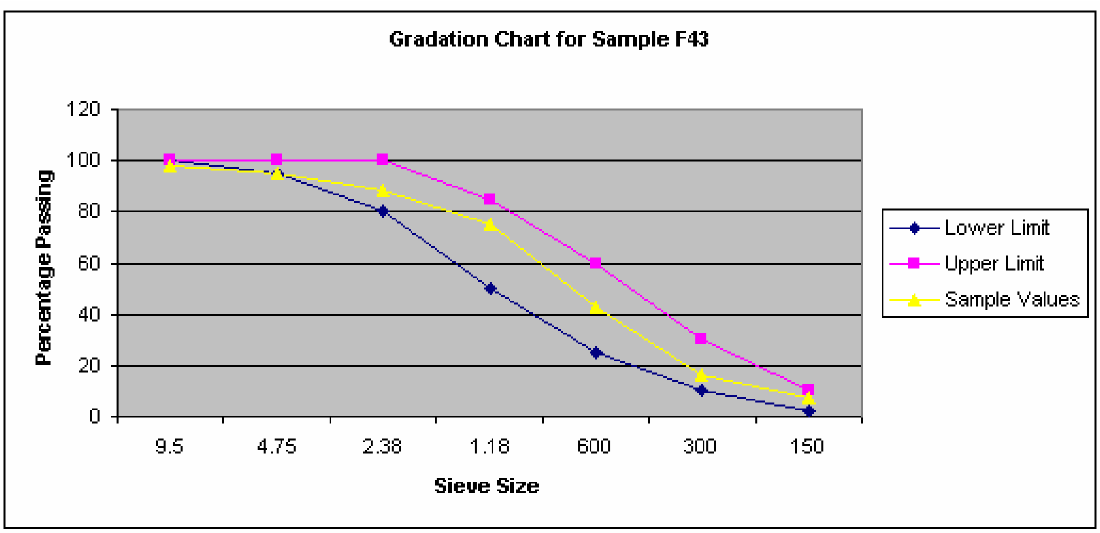

Gradation Chart for Sample F40
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values



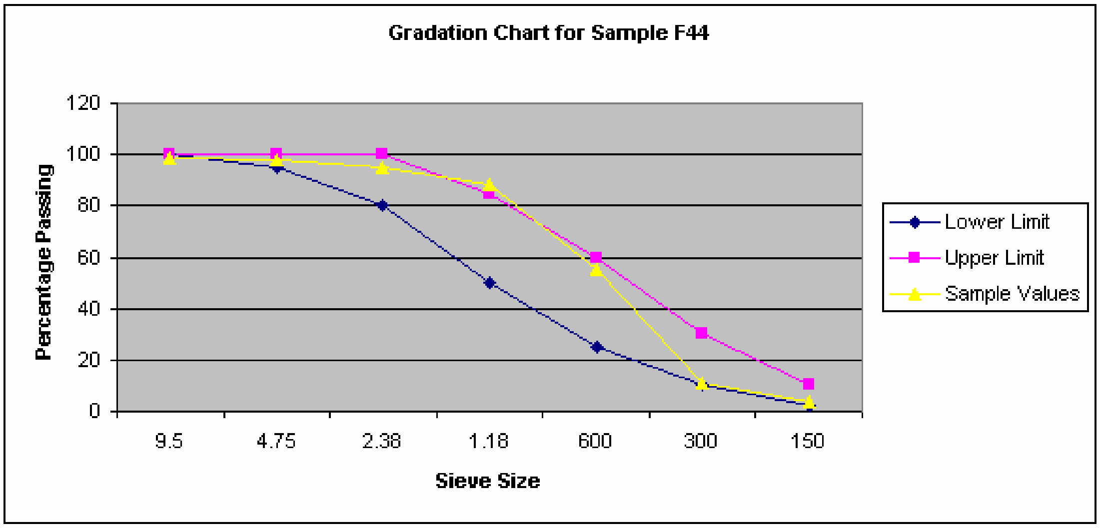
Gradation Chart for Sample F41
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

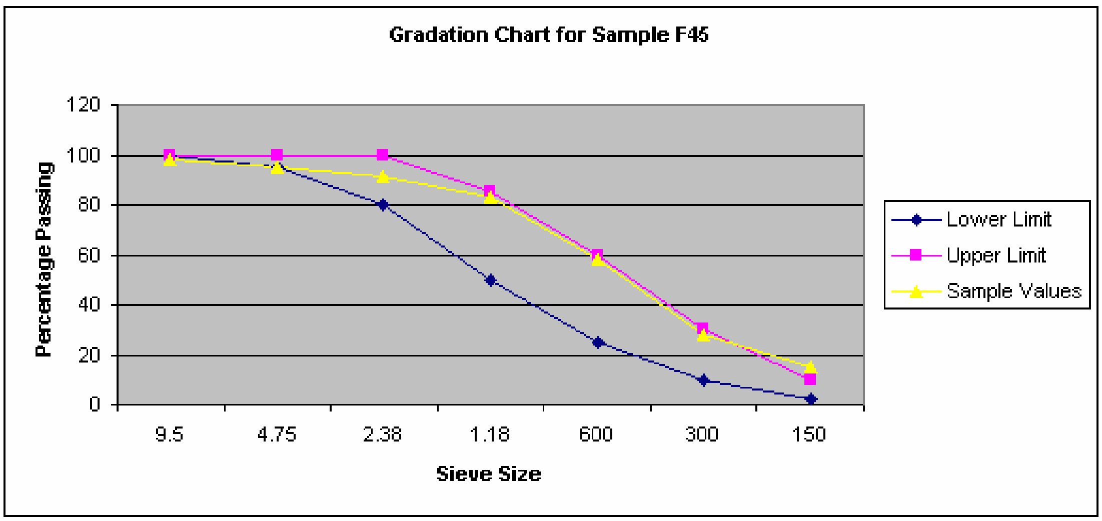


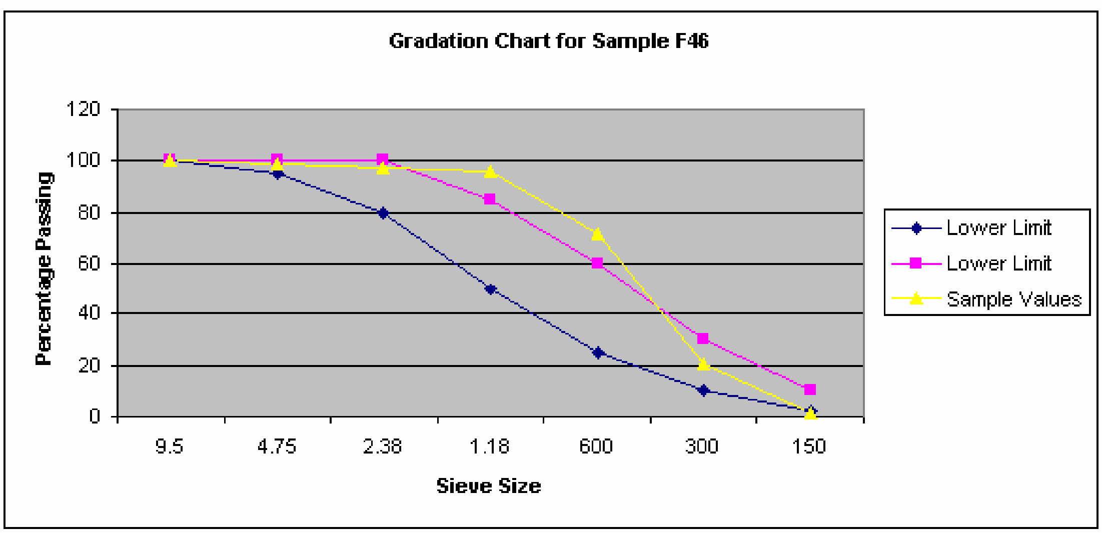
Gradation Chart for Sample F42
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

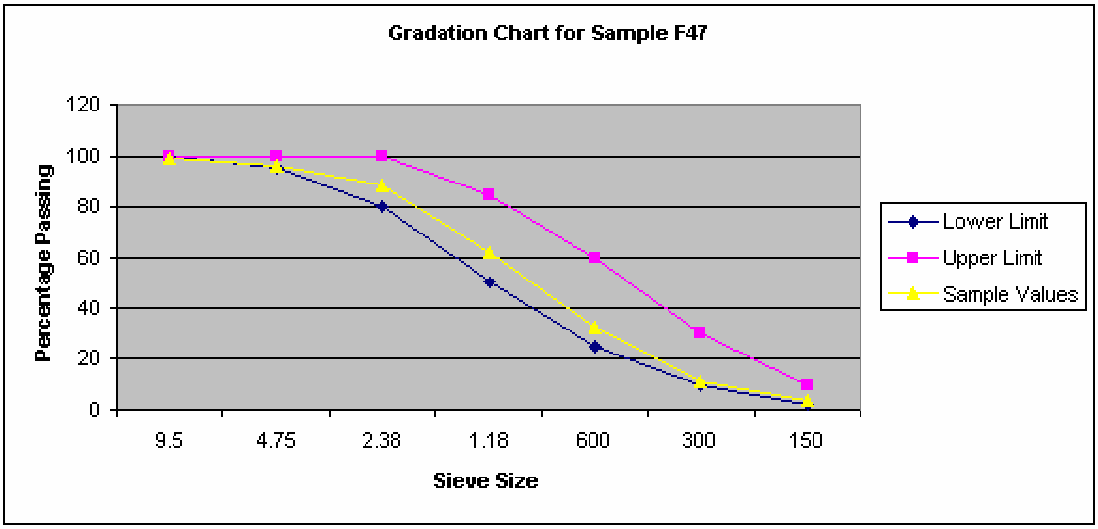


Gradation Chart for Sample F43
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values


Gradation Chart for Sample F44
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

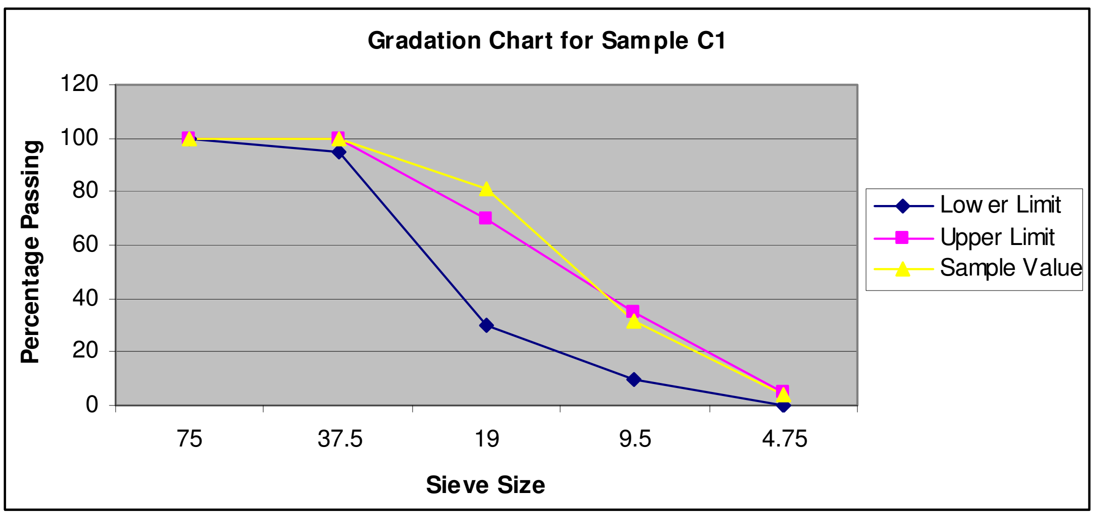

Gradation Chart for Sample F45
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Upper Limit
Sample Values

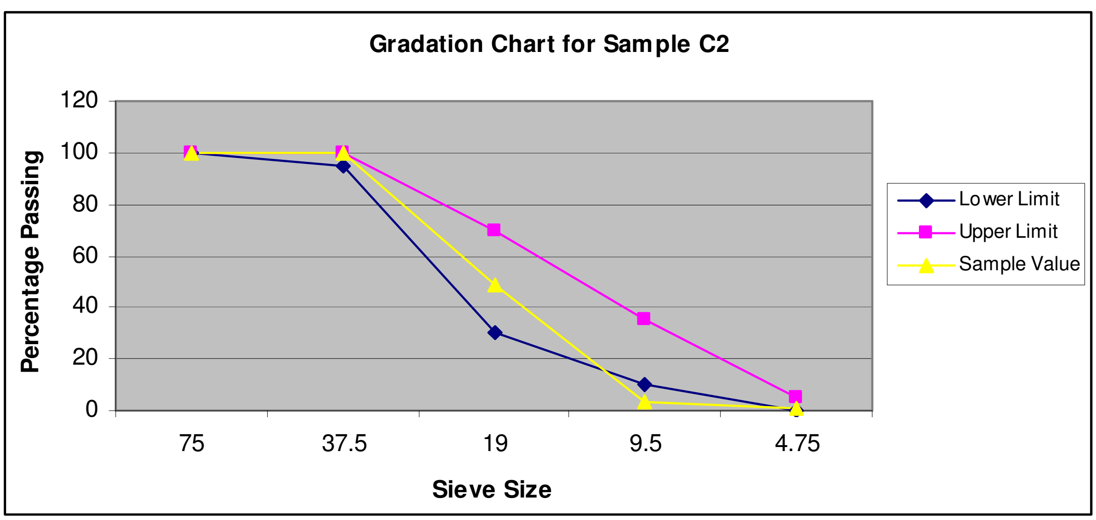

Gradation Chart for Sample F46
Percentage Passing
120
100
80
60
40
20
0
9.5
4.75
2.38
1.18
600
300
150
Sieve Size
Lower Limit
Lower Limit
Sample Values

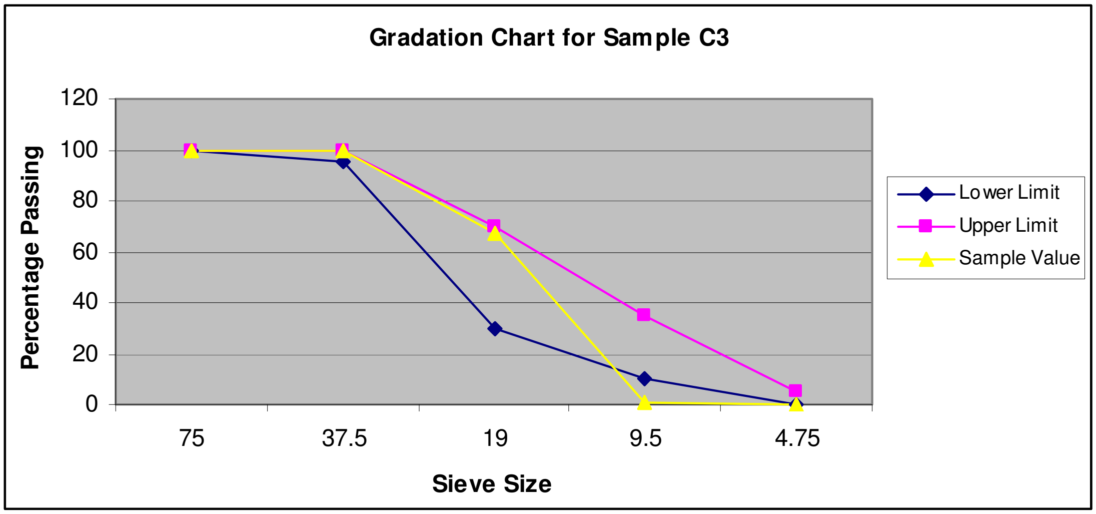


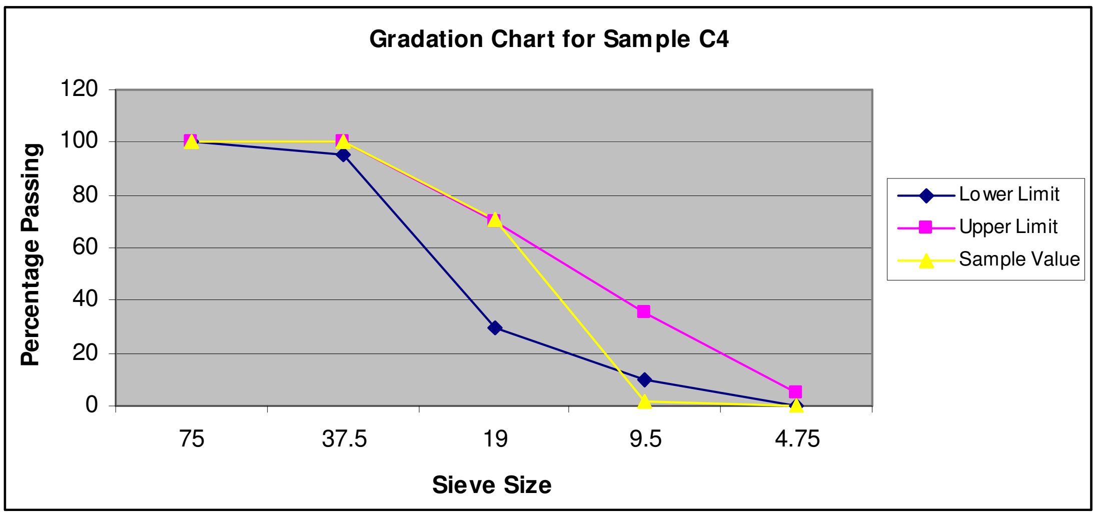
C2 Coarse Aggregates

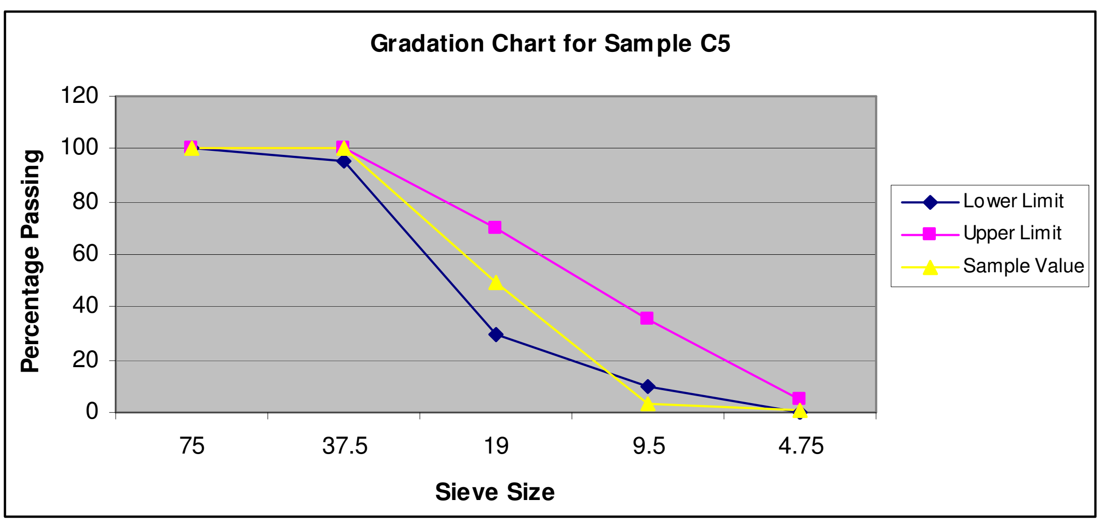
- **Coarse Aggregate Samples with nominal maximum aggregate size of 37.5 mm**

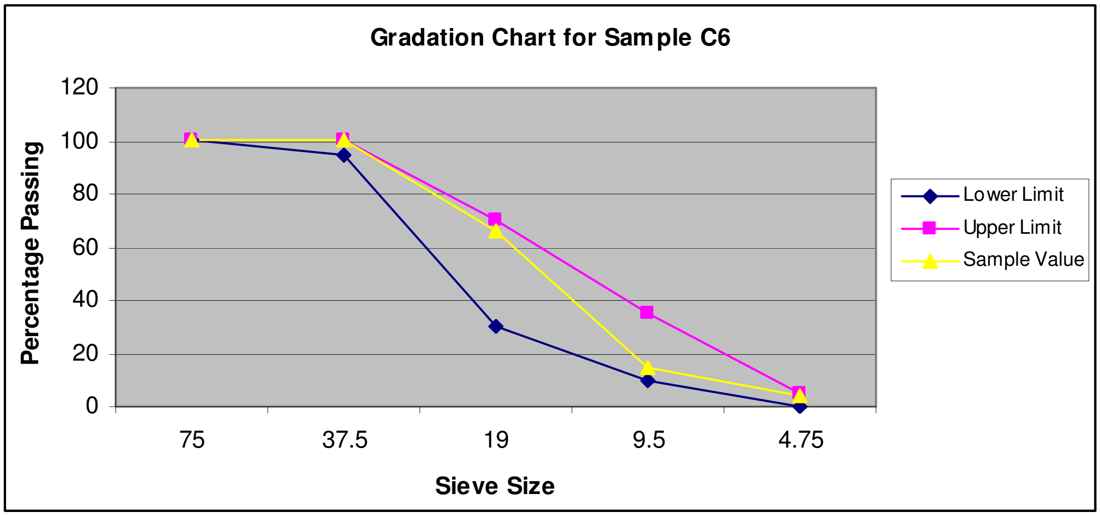


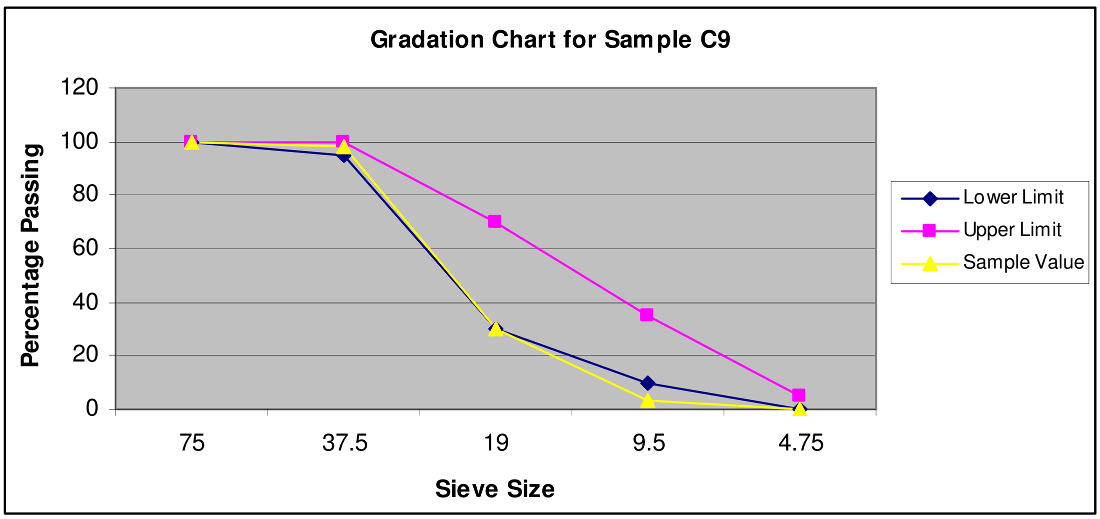


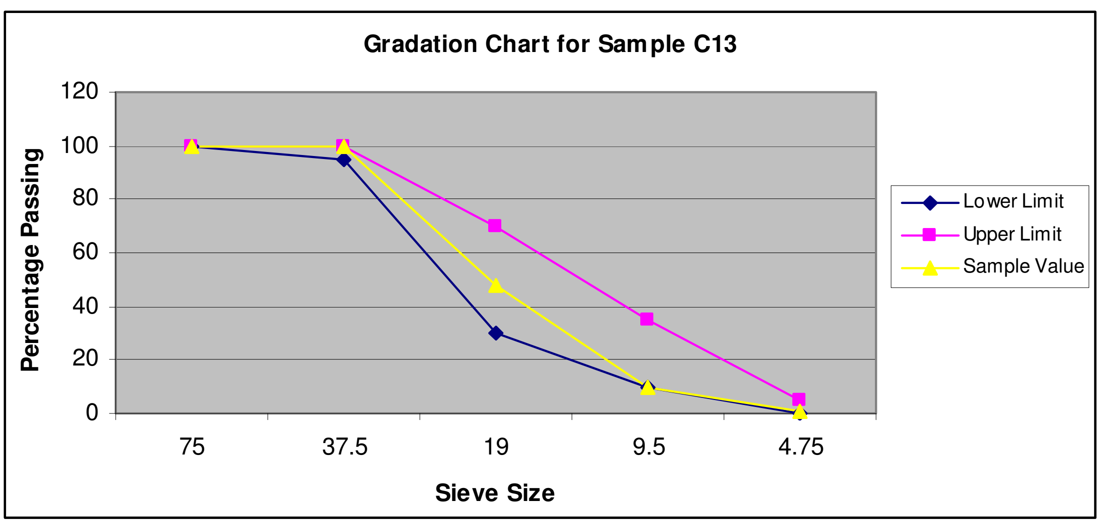

Gradation Chart for Sample C3
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

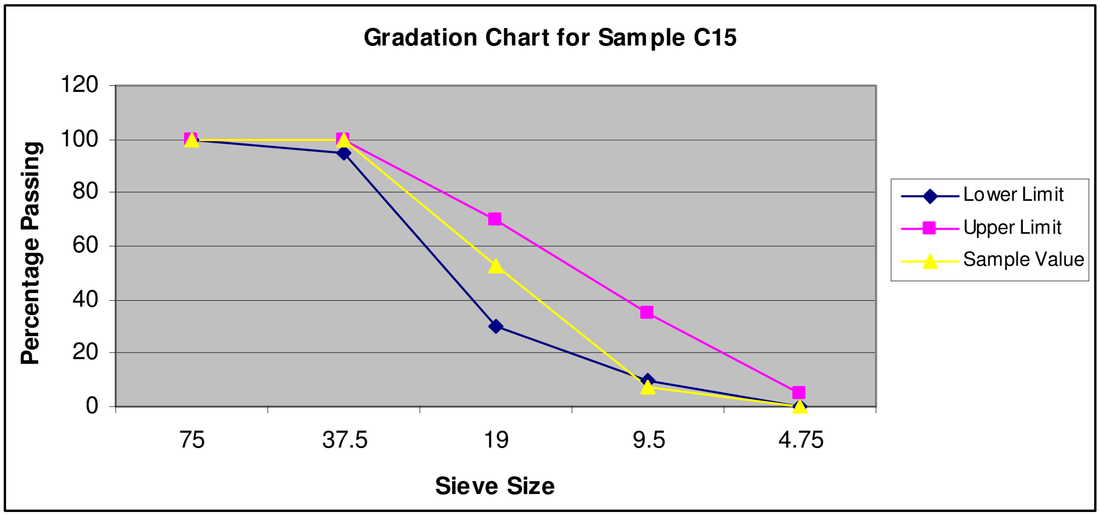

Gradation Chart for Sample C4
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

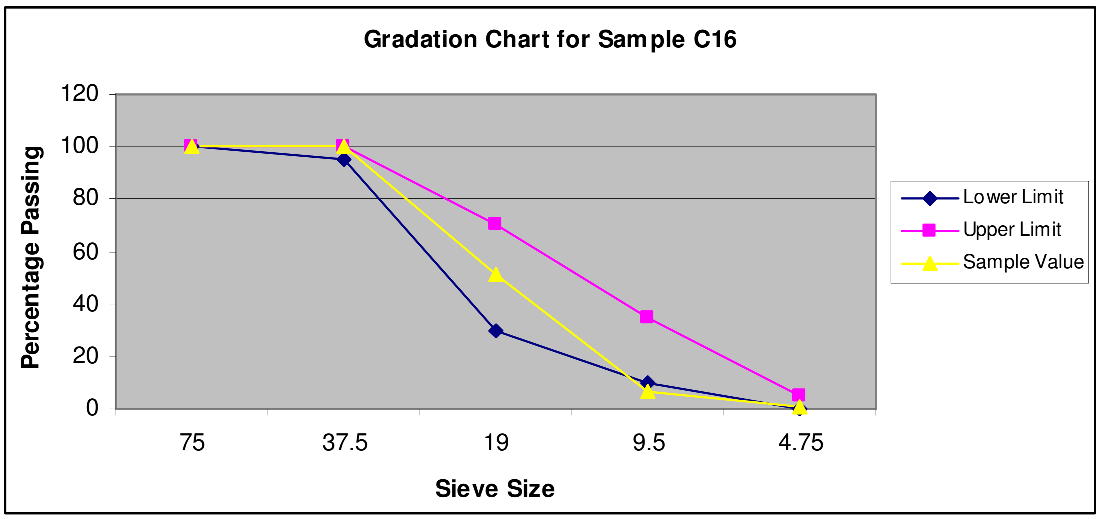

Gradation Chart for Sample C5
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

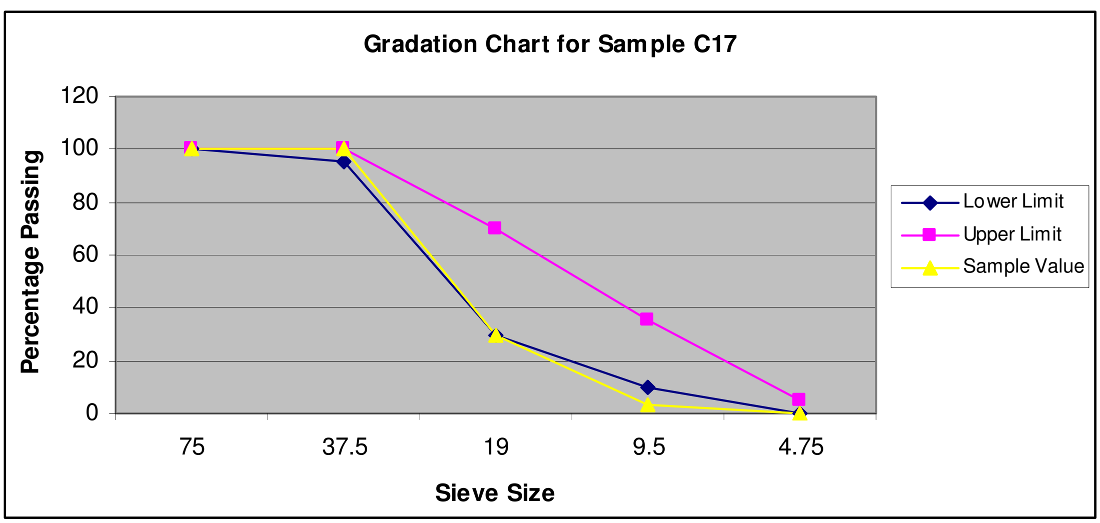

Gradation Chart for Sample C6
Percentage Passing
Sieve Size
Lower Limit
Upper Limit
Sample Value
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75

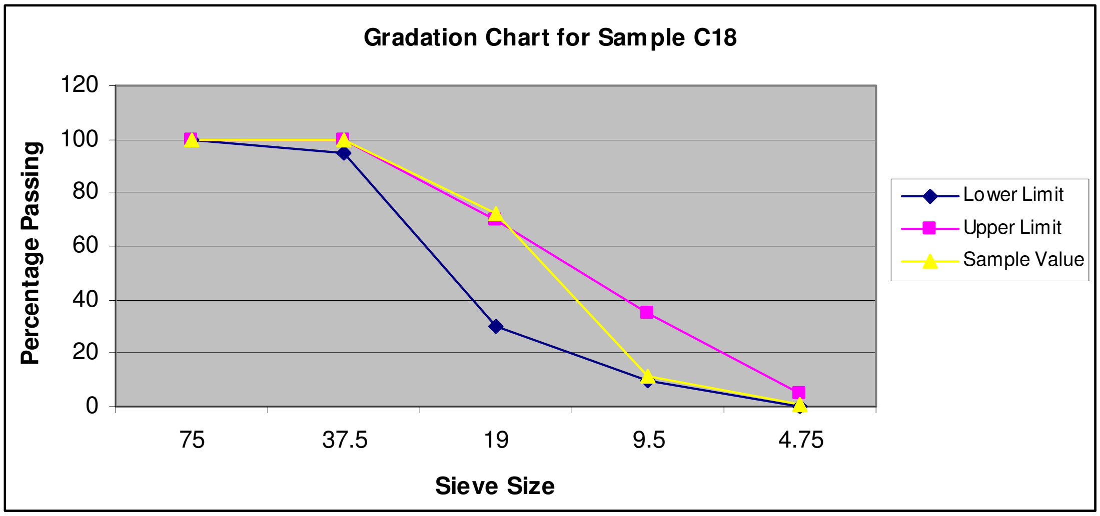

Gradation Chart for Sample C9
Percentage Passing
Sieve Size
Lower Limit
Upper Limit
Sample Value
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75

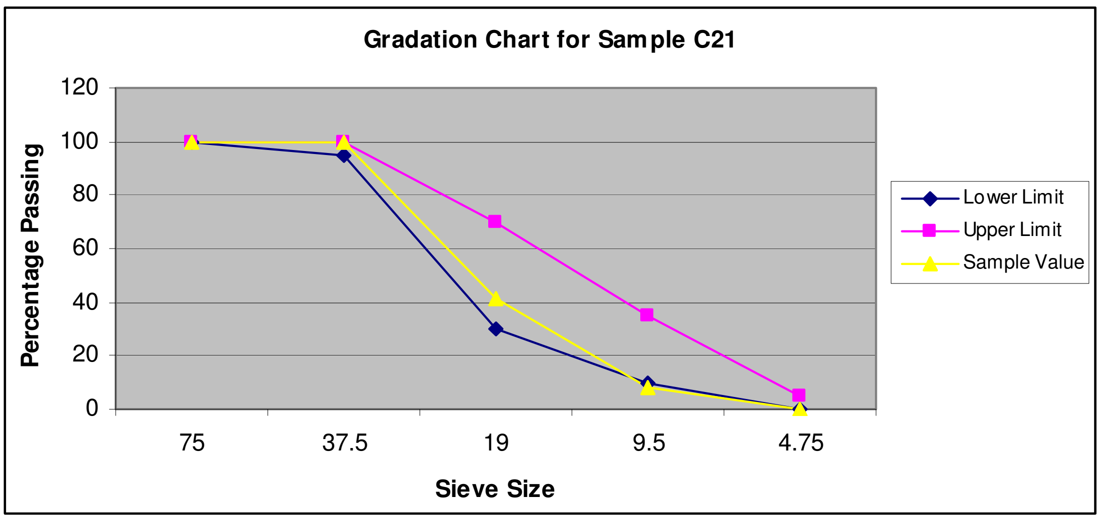

Gradation Chart for Sample C13
Percentage Passing
Sieve Size
Lower Limit
Upper Limit
Sample Value
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75

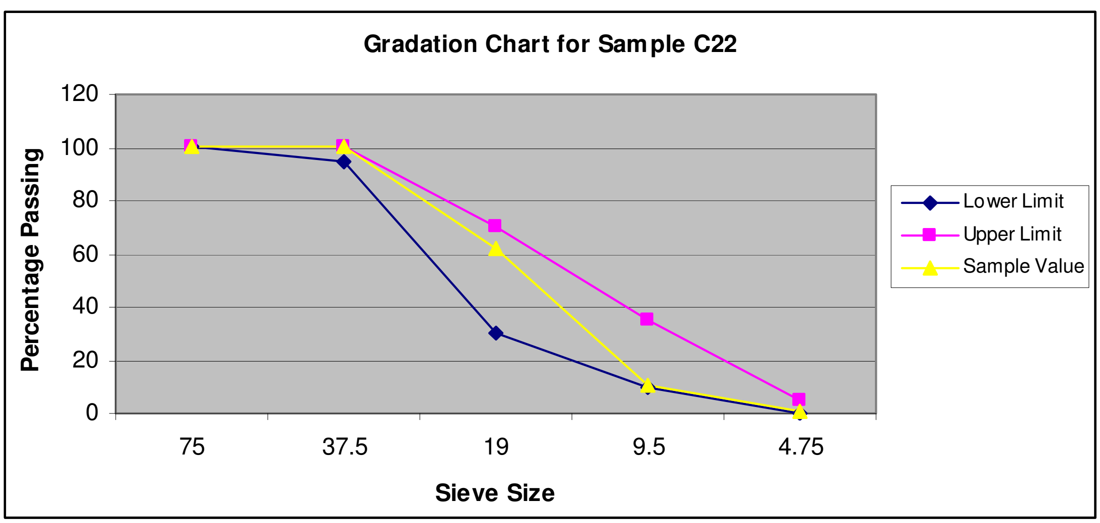

Gradation Chart for Sample C15
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

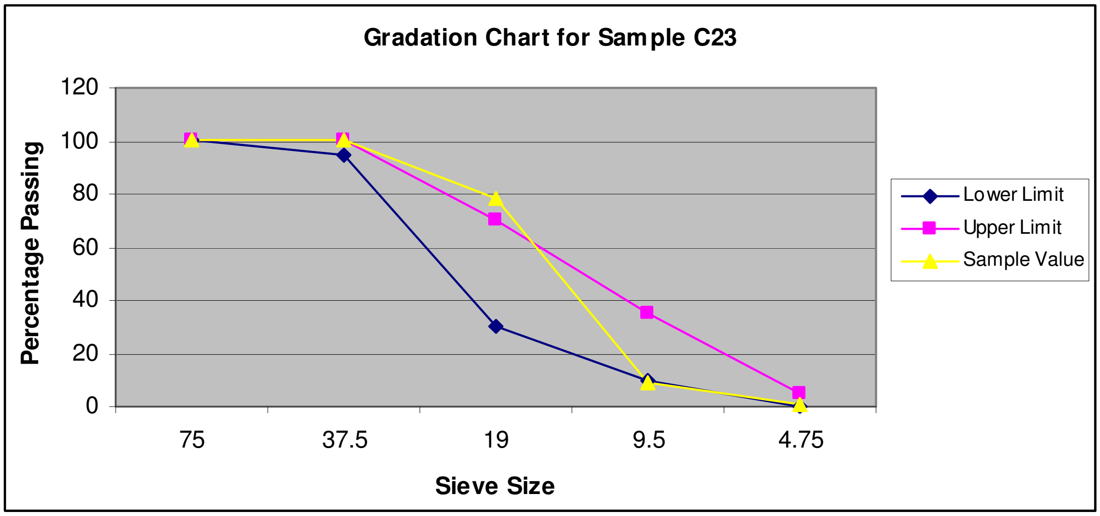

Gradation Chart for Sample C16
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

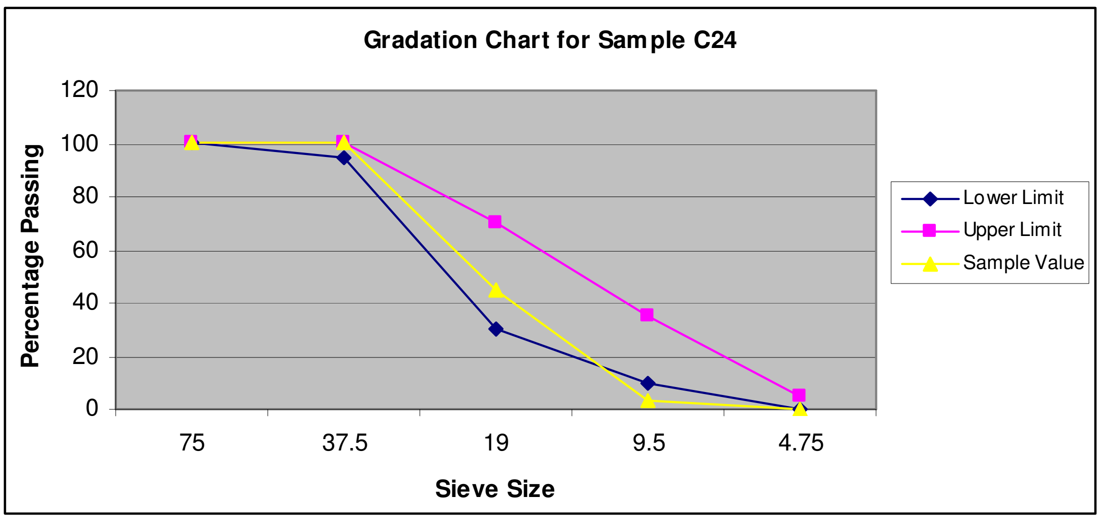

Gradation Chart for Sample C17
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

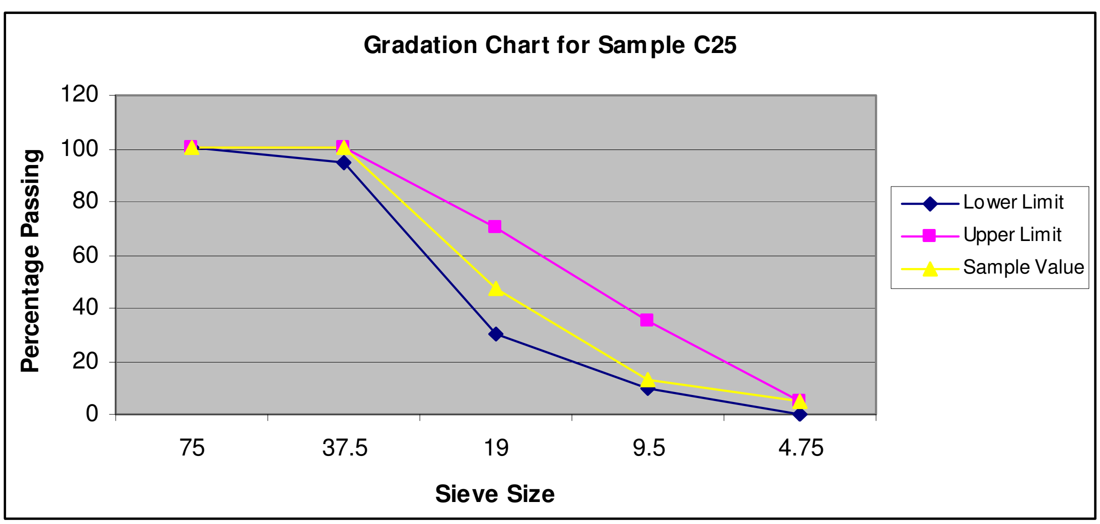

Gradation Chart for Sample C18
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

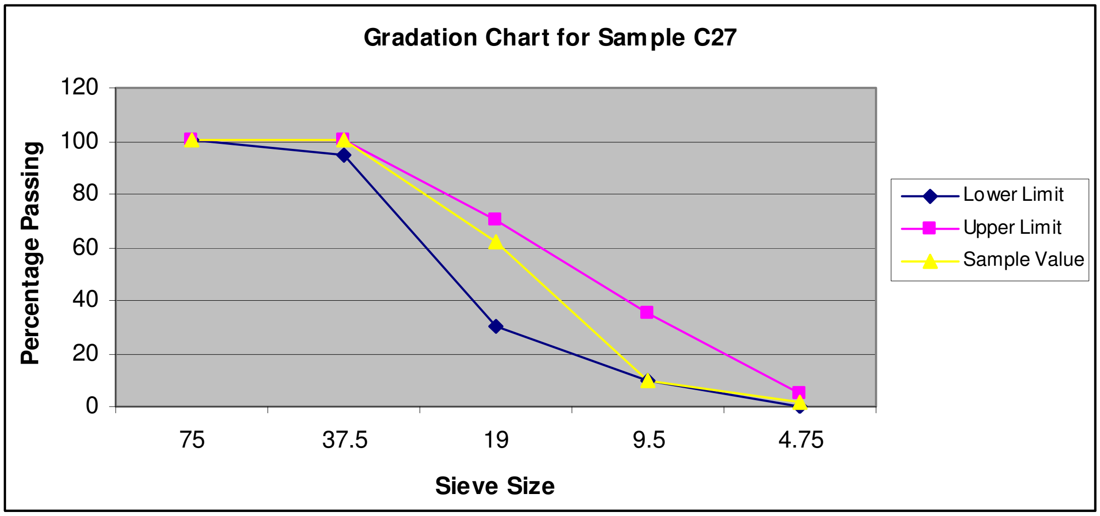

Gradation Chart for Sample C21
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

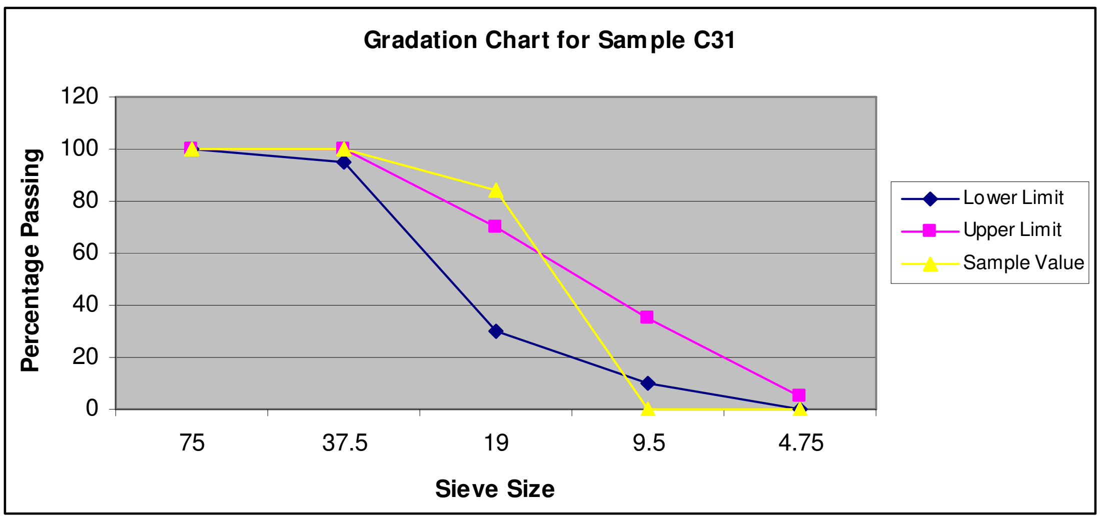

Gradation Chart for Sample C22
120
100
80
60
40
20
0
Percentage Passing
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

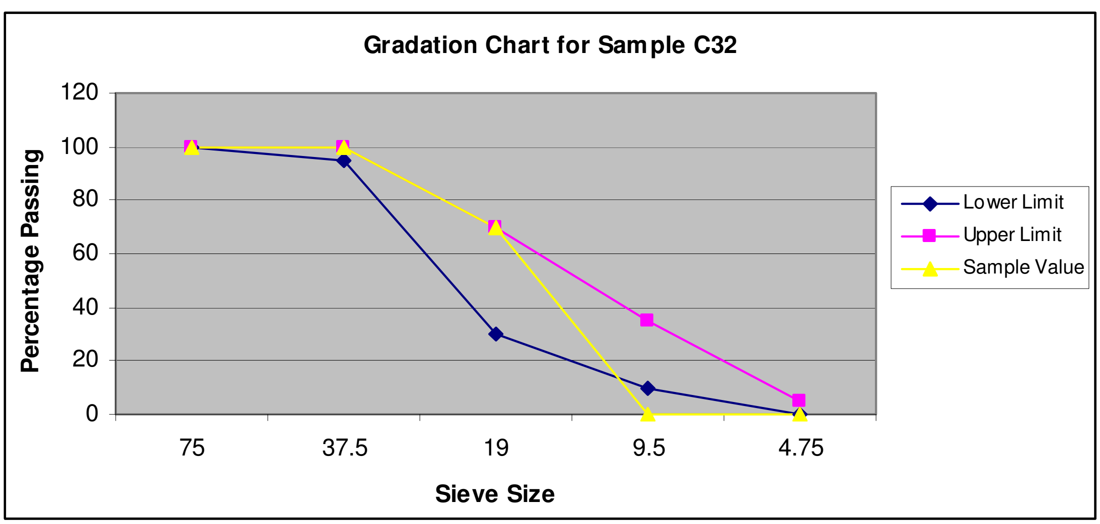

Gradation Chart for Sample C23
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

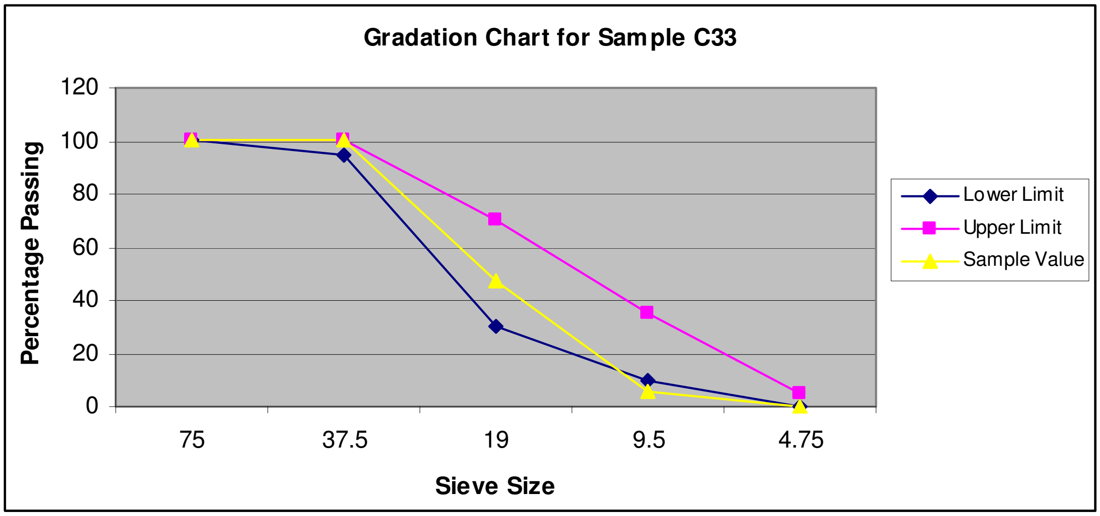

Gradation Chart for Sample C24
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

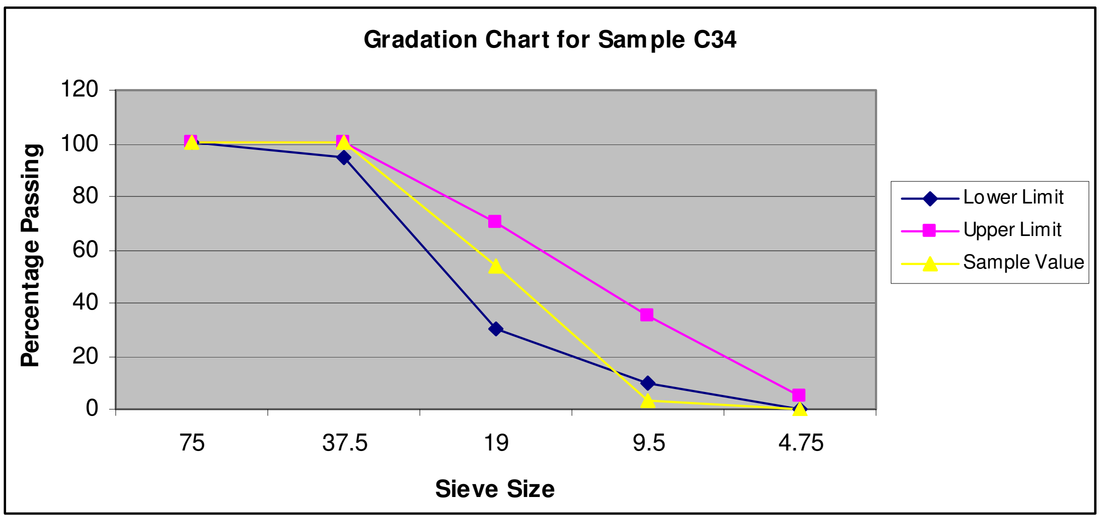

Gradation Chart for Sample C25
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value


Gradation Chart for Sample C27
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

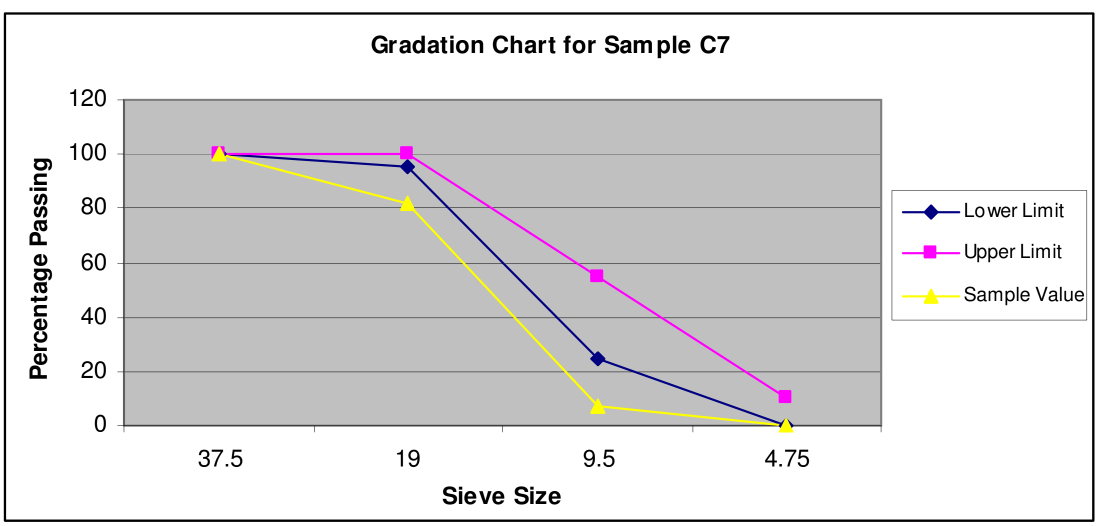

Gradation Chart for Sample C31
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

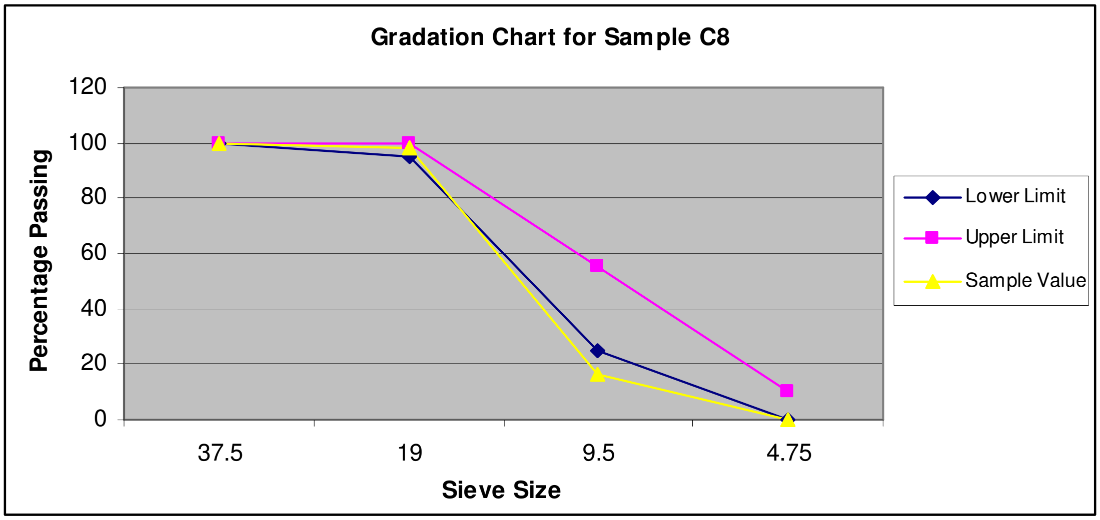

Gradation Chart for Sample C32
Percentage Passing
120
100
80
60
40
20
0
75
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

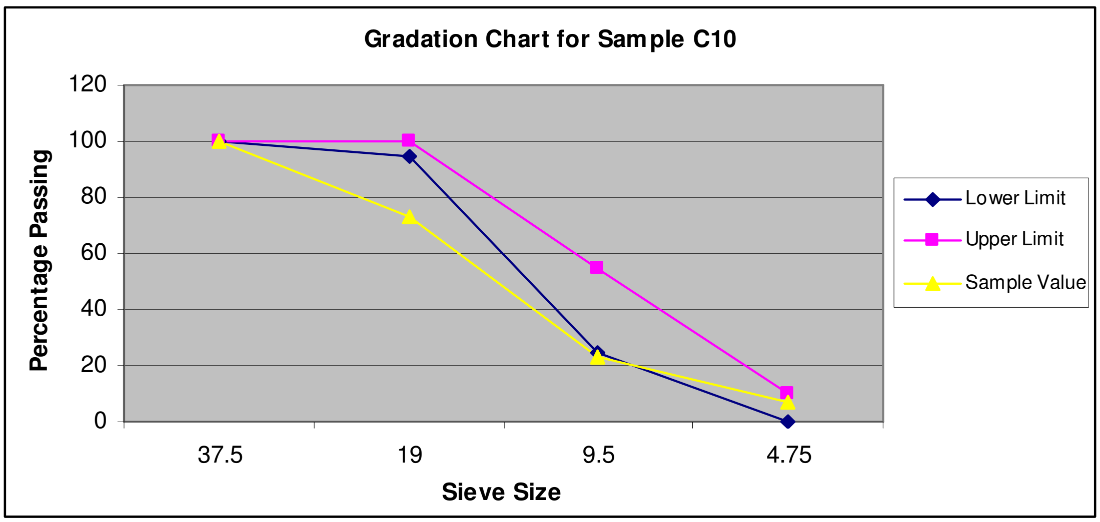


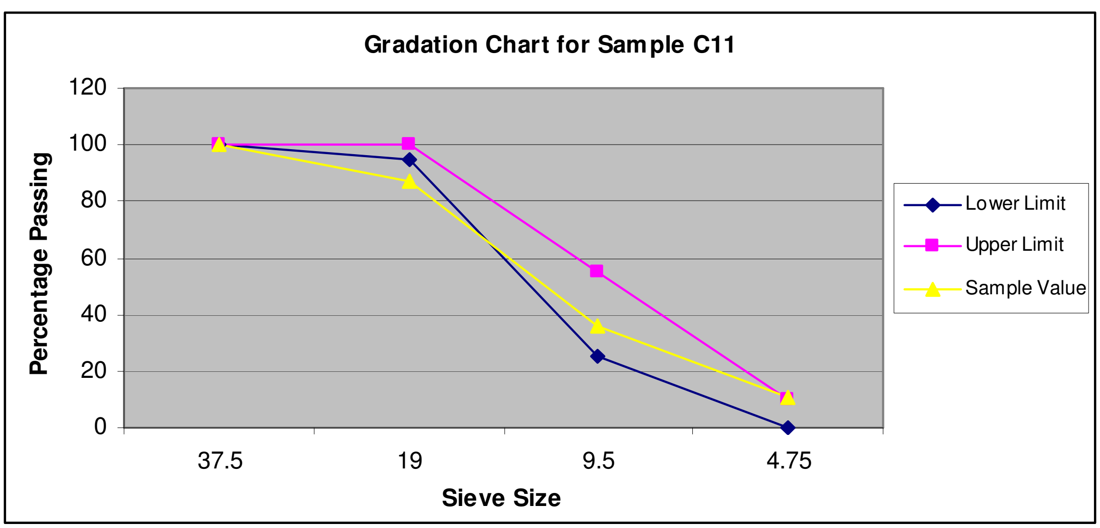


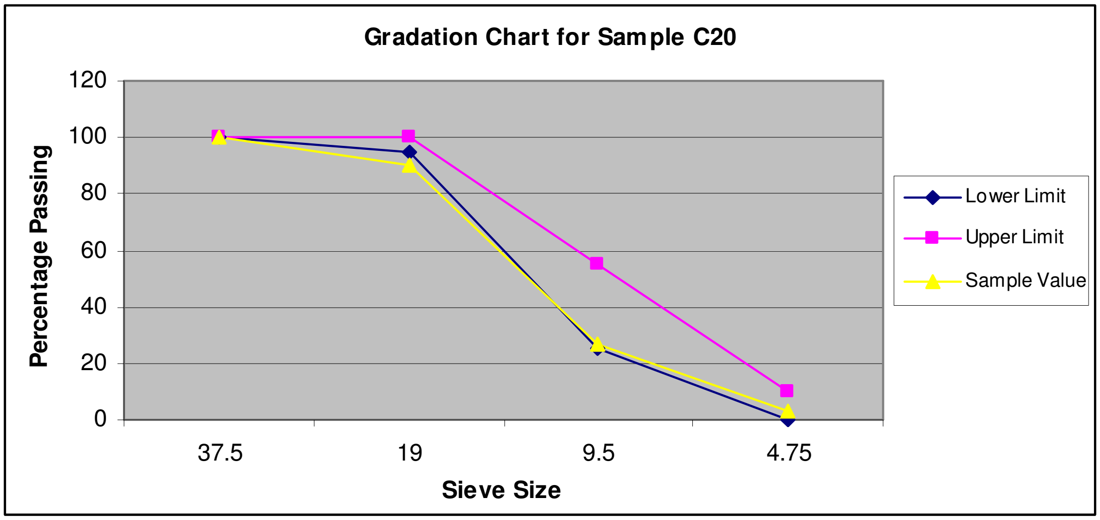
- **Samples with nominal maximum aggregate size of 19.5 mm**

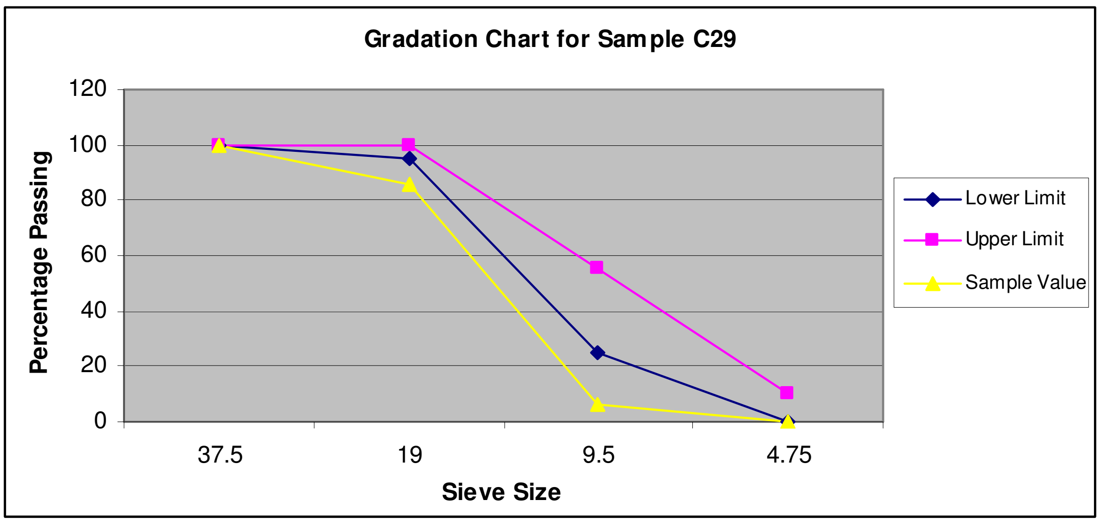


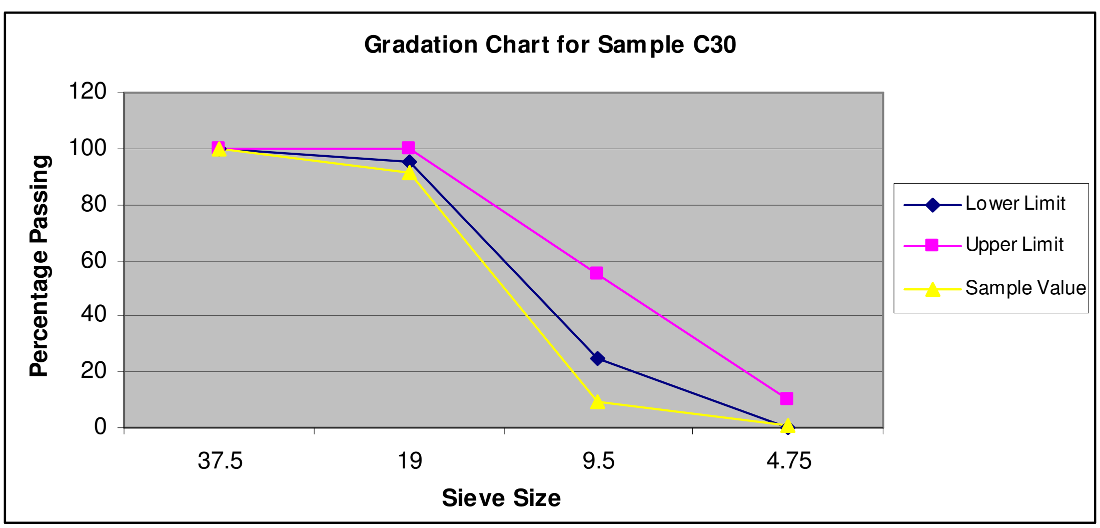

Gradation Chart for Sample C8
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value


Gradation Chart for Sample C10
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

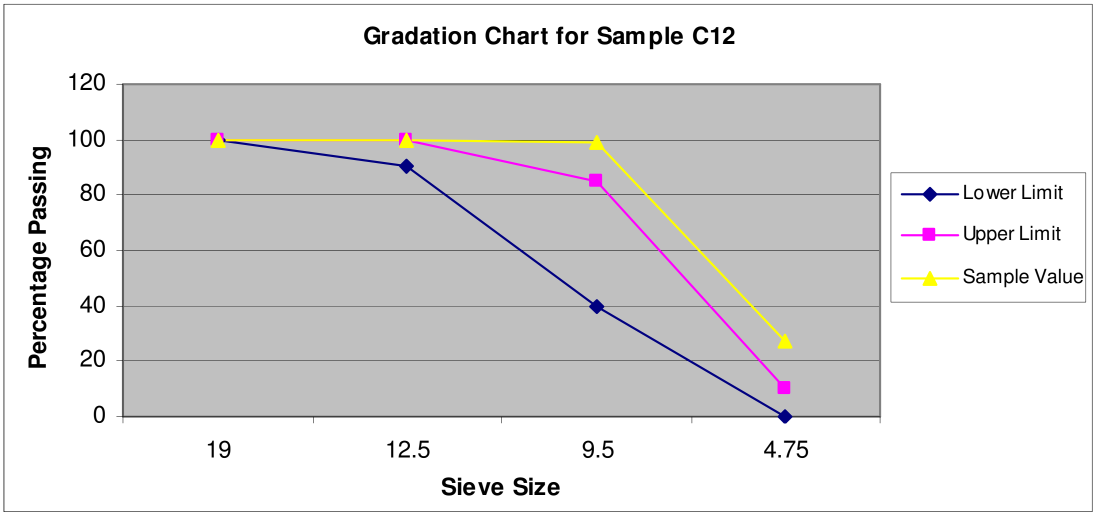

Gradation Chart for Sample C11
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

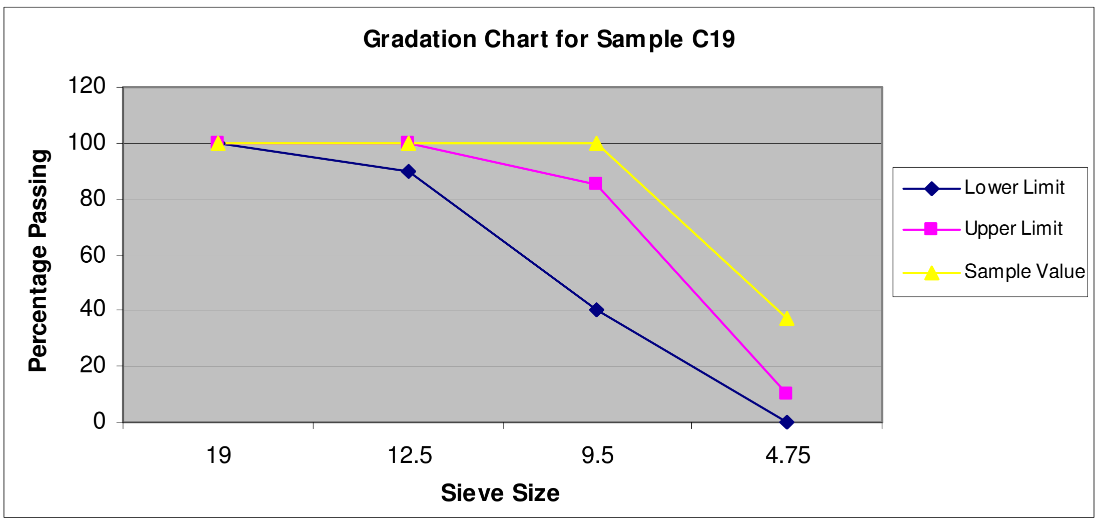

Gradation Chart for Sample C20
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

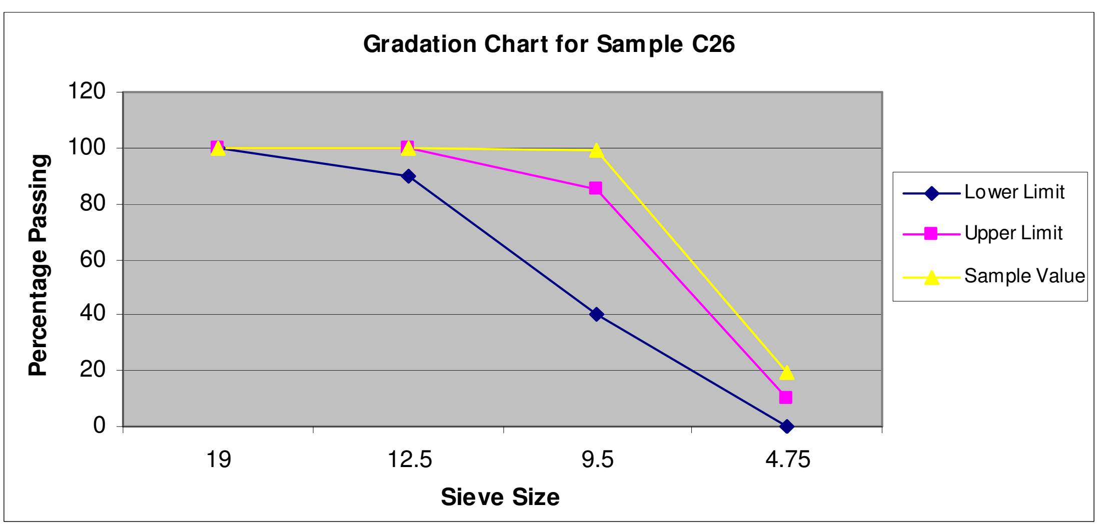

Gradation Chart for Sample C29
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

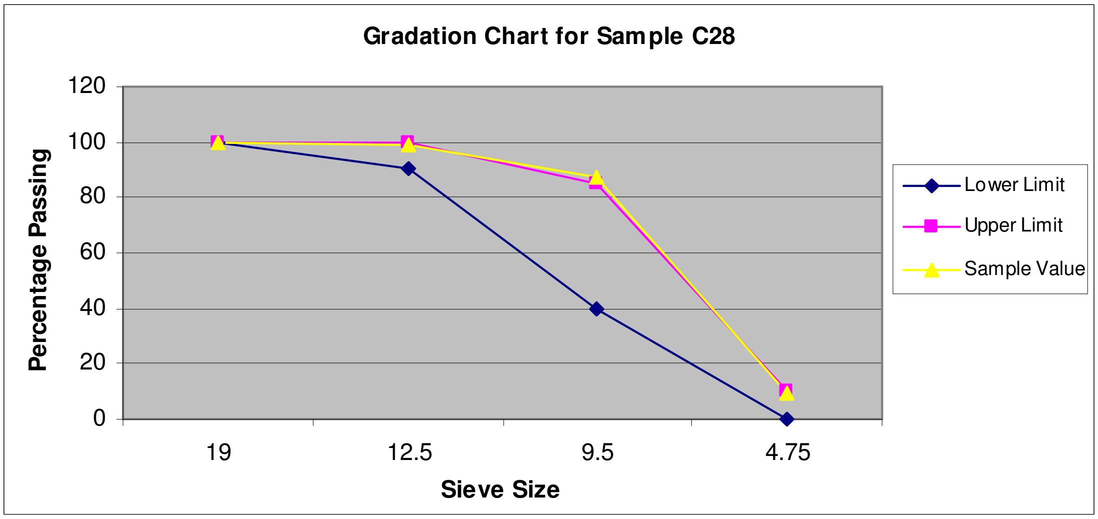

Gradation Chart for Sample C30
Percentage Passing
120
100
80
60
40
20
0
37.5
19
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

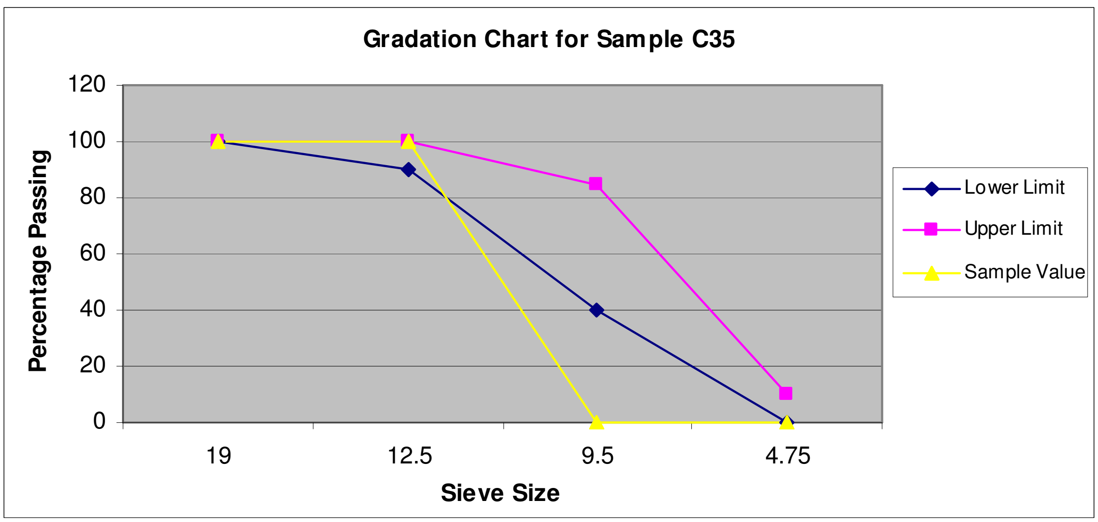
- **Samples with nominal maximum aggregate size of 13.5 mm**

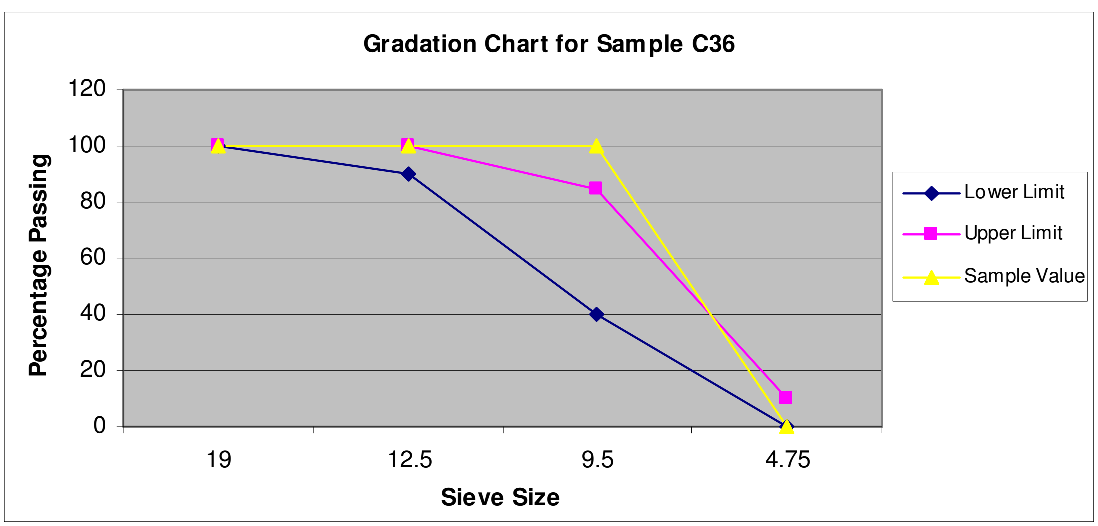







Gradation Chart for Sample C28
Percentage Passing
120
100
80
60
40
20
0
19
12.5
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value


Gradation Chart for Sample C35
Percentage Passing
120
100
80
60
40
20
0
19
12.5
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value


Gradation Chart for Sample C36
Percentage Passing
120
100
80
60
40
20
0
19
12.5
9.5
4.75
Sieve Size
Lower Limit
Upper Limit
Sample Value

Annex D

D1 Organic Impurities and silt and clay contents of the fine aggregate samples

Sample	Organic Impurity (Plate Number)	Silt and Clay Content (%)
F1	2	**1.98**
F2	4	4.13
F3	1	8.89
F4	2	1.35
F5	2	-
F6	3	-
F7	3	-
F8	2	-
F9	2	-
F10	2	1.88
F11	1	2.60
F12	2	0.99
F13	2	1.88
F14	1	2.49
F15	1.23	-
F18	2	6.15
F19	2	5.28
F20	3	2.77
F21	2	5.36
F22	4	6.77
F23	2	4.93
F24	3	4.71
F25	2	6.37
F26	-	6.88
F27	2	6.27
F28	3	4.90
F29	3	3.56
F30	2	4.73
F31	2	2.75
F32	2	0.77
F33	1	1.50
F34	3	1.45
F35	2	4.26
F36	2	5.12
F37	3	1.16
F38	2	5.23
F39	1	3.82
F40	2	2.30
F41	1	1.49
F42	2	2.04
F43	3	5.50
F44	2	2.93
F45	3	12.62
F46	1	2.35
F47	2	2.35
ES requirement	3[16]	<=3.0 [17]

[16] ASTM C40
[17] ES C. D3.201

D2 Organic Impurities and silt and caly contents of the coarse aggregate samples

Sample	Silt and Clay Content (%)
C33	1.50
C34	1.45
C35	4.26
C36	5.12
C37	1.16
Requirement	1[18]

[18] ASTM C117

Annex E

E1 Unit weights of the tested fine aggregate samples

Sample	Loose Unit Weight (kg/m^3)	Compacted Unit Weight (kg/m^3)
F1	1239	1372
F2	900	1011
F3	989	1100
F4	1050	1161
F5	1111	1239
F6	1189	1338
F7	1056	1167
F8	756	850
F9	1206	1367
F10	1144	1300
F11	1383	1522
F12	1517	1667
F13	1450	1583
F14	1572	1661
F21	1150	1294
F28	998	1199
F35	1350	1450
F36	1183	1350
F40	1189	1378
F41	1417	1550
F43	1100	1133
F44	1239	1294
F45	1039	1172
Requirement	1520 - 1680	1520 - 1680

E2 Unit Weights of the tested coarse aggregate samples

Sample	Loose Unit Weight (kg/m^3)	Compacted Unit Weight (kg/m^3)
C1	1550	1736
C2	1350	1552
C3	1312	1521
C4	1369	1562
C5	1345	1566
C6	1384	1586
C9	1276	1505
C15	1448	1671
C16	1436	1679
C18	1288	1464
C23	1590	1633
C27	1493	1716
C29	1362	1569
C31	1264	1479
C32	1414	1641
Requirement	1245 – 1825	1245 – 1825

E3 Unit Weights of the rock samples

Designation	Unit Weights	
	Loose(kg/m^3)	Compacted(kg/m^3)
R1	1464	1700
R3	1433	1691
R4	1429	1679
Requirement	1245 – 1825	1245 – 1825

Annex F

F1 Specific Gravity and Water Absorption of the tested fine aggregate samples

Sample	Specifc Gravity			Water Absorption (%)
	Bulk	Bulk (SSD)	Apparent	
F10	2.20	2.34	2.55	5.25
F11	2.51	2.53	2.56	0.79
F12	2.64	2.67	2.72	1.18
F13	2.61	2.66	2.70	0.88
F14	2.54	2.63	2.81	3.82
F16	2.26	2.33	2.45	3.28
F17	2.40	2.49	2.62	2.54
F21	2.21	2.34	2.53	5.75
F28	2.22	2.30	2.41	3.52
F41	2.57	2.62	2.71	1.90
ES requirement	2.4 – 3.0	2.4 – 3.0	2.4 – 3.0	0.2 – 4.0

F2 Specific Gravity and Water Absorption of the tested coarse aggregate samples

Sample	Specifc Gravity			Water Absorption
	Bulk	Bulk (SSD)	Apparent	
C1	2.67	2.71	2.73	0.84
C2	2.46	2.53	2.63	2.55
C3	2.57	2.58	2.61	0.57
C4	2.57	2.60	2.65	1.12
C5	2.63	2.64	2.66	0.54
C6	2.61	2.62	2.63	0.31
C9	2.53	2.56	2.60	1.11
C10	-	2.22	-	2.23
C11	-	2.75	-	1.58
C15	2.73	2.78	2.89	2.08
C16	2.71	2.74	2.79	1.07
C18	2.46	2.52	2.61	2.23
C28	2.57	2.62	2.68	0.64
C29	2.54	2.55	2.57	0.57
C31	2.47	2.50	2.56	1.38
Requirement	2.4 – 3.0	2.4 – 3.0	2.4 – 3.0	0.2 – 4.0

F3 Specific gravities and water absorption values of the rock samples

Designation	Specific Gravity			Water Absorption
	Bulk	Bulk (SSD)	Apparent	
R1	2.58	2.64	2.75	2.42
R2	-	-	-	6.14
R3	2.69	2.73	2.80	1.45
R4	2.64	2.67	2.72	1.18
Requirement	2.4 – 3.0	2.4 – 3.0	2.4 – 3.0	0.2 – 4.0

ANNEX G

G1 Los Angeles Abrasion and Aggregate Crushing Values of the Coarse Aggregate Samples

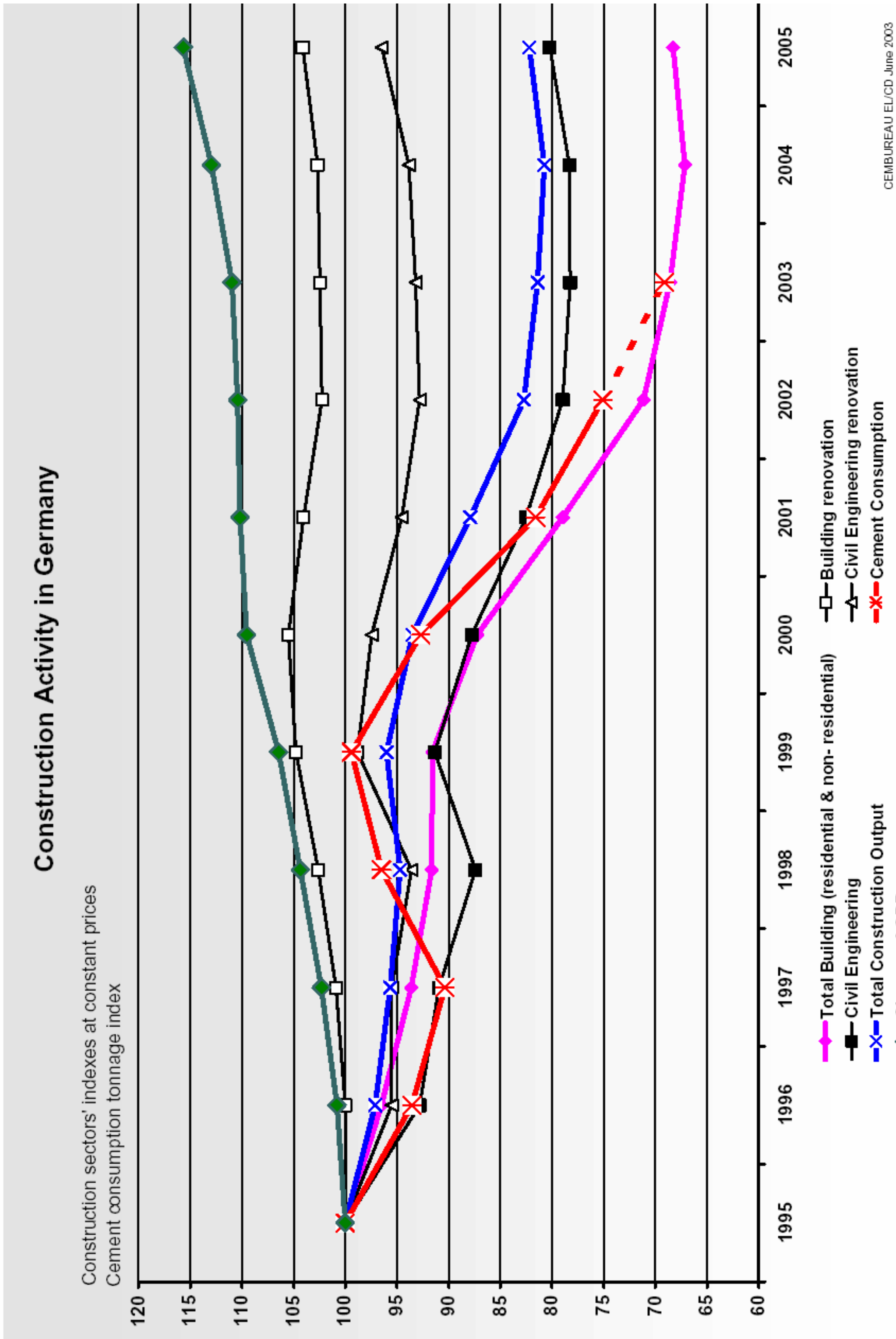
Sample	Los Angeles Abrasion(%)	Aggregate Crushing Value	Flakiness Index
C1	14.20	-	-
C2	48.84	-	-
C3	-	35	23.04
C4	-	43	23.86
C5	-	43	28.61
C6	-	40	32.68
C10	22.00	31	11.00
C11	16.00	-	-
C13	15.32	-	-
C14	-	-	-
C15	15.10	-	-
C16	12.00	-	-
C17	13.60	-	-
C18	15.60	-	-
C22	13.14	-	-
C23	17.56	-	-
C24	17.04	-	-
C25	15.26	-	-
C27	15.56	-	-
C29	28.34	-	-
C30	11.00	-	-
C32	16.90	-	-
C33	33.00	-	-
C34	31.50	-	-
C37	14.26	-	-
Requirement	<=50	<= 40	<= 35

G2 Los Angeles Abrasion values of the tested rock samples

Designation	Los Angeles Abrasion Value	Soundness by Sodium Sulphate Method (%) Loss	Flakiness Index
R1	-	5.62	-
R2	30.00	-	-
R3	13.26	2.09	33
R4	13.30	3.10	30
Requirement	<=50	<= 12	<= 35

ANNEX H   CONSTRUCTION ACTIVITY IN GERMANY (1995 – 2005)

(Source : The European Cement Association, Country Report 2005.)



DECLARATION

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

Name	Denamo Addissie
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Date of submission	October 2005

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

Name	____________________
Signature of the Advisor	____________________
Date	____________________