Characterization of Borkena River Natural Sand, Above Borkena Bridge in Ethiopia Used for the Production of C-25 Concrete

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Abstract— **Natural river sand is a term used for aggregates having size less than 4.75mm obtained from natural disintegration of rock and deposited in river beds. It is mainly excavated from river beds and most of the time contains high percentages of silt/clay and organic materials that adversely affect the strength and durability of concrete and reinforcing steel by reducing life of the structure. The main objective of this research is the characterization of natural river sand used for the production of C-25 Concrete. In this research natural river sand sample were collected Above Borkena Bridge (ABB) which is located in kombolcha city, Ethiopia, and their physical properties were studied. The experiments were performed on C-25 concrete grade mixed with 0.491 W/C ratio with a slump of 25-50mm. Concrete Cube was casted from each batch of the mix by original source not washed, keeping all parameters as constant. In addition to this, concrete cubes with (original) sand source. A total of 30 cube samples were prepared for testing at ages of 7days and 28 days for the sand sources. The result of this research shows that the compressive strength of ABB at age of 7days is 32.85Map and at 28days is 45.9Map, for 28days increased with 2.18% of silt/clay content.**

Index Terms— **Compressive Strength, Silt/Clay Content, River Sand, Workability, Concrete**

I. Introduction

Concrete is widely used man made construction material made from commonly available materials such as cement, aggregates and water. Admixtures can be added to concrete to achieve tailor-made properties to meet any demand that may arise in the given situation [1]. Mixture of crushed stone or gravel, sand, cement and water that hardens as it dries and attains strength not unlike stone. First used by the Romans [2]. Whether used in building, bridges, pavement or any other of its numerous areas of service concrete must have strength and, the ability to resist force [3]. Basically, concrete is a mixture of sand, rocks, and a binder. Concrete is one of the most common construction materials [4].

Natural river sand is sand from the natural disintegration of rock and which has been deposit by streams or glacial agencies. It can be obtained from various sources, river, run off, sand deposit etc. and most of the time contains high percentages of organic materials, chlorides, sulphates, silt and clay (i.e. sub 75μm) that adversely affect the strength and durability of concrete and reinforcing steel by reducing the life of structure [5]. High percentages of sand in hardened concrete have an impact on the cost effectiveness of the concrete. That is why the materials for construction should be sampled, inspected, tested prior to use if they meet the established standards in all respects. Fine aggregates such as sand used in concrete production may contain excessive silt and clayey contents as well as organic impurities that impact negatively on the quality of hardened concrete.

Sand is the principal component of concrete, the critical construction material and deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers may be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion. Whichever size the producer decides to eliminate for quality reasons, obviously, also affects the sizing [6].

Naturally existing natural river sand material does not exist in pure forms ie it consists of some impurities. Impurities can be classified as solid materials or soluble substances. Solid materials are generally present in a very finely divided state, passing the 75-μm sieve. Such materials will appreciably increase the water requirements for workable concrete and reduce the abrasion resistance of hardened concrete if present in large amounts. The fine fraction is also likely to stick to the surfaces of the large aggregate particles, isolating those particles from the surrounding concrete and causing a reduction in strength. Materials in this class are commonly silt, clay, rock dust, and organic matter [7].

The coarseness of fine aggregates is determined by the percentage retained on the 300 μm sieve. ASTM C33 allows for as little as 10 per cent of fine aggregates passing through the 300 μm sieve. Too little of the minus-300 μm fraction can lead to harshness, a lack of cohesion and segregation. Too much will lead to a sticky mix with excessive water requirement [8].

Sand is a product of natural or artificial disintegration of rocks and minerals obtained from glacial, river, lake, marine, residual and wind-blown deposits. These dumps however do not only provide sand but also contain other materials such as dust, loam, silt and clay that are finer than sand.There are three broad categories of organic matter in sands; humid, non-humid and organic contaminants [9].

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The aggregate impact value shall not exceed 45 % by weight for aggregates used for concrete other than wearing surfaces and 30% by weight for concrete for wearing surfaces such as runways, roads and pavements [1].

Aggregate for concrete As per ACI E-701, Aggregate is granular material such as sand, gravel, crushed stone, blast-furnace slag, and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete. Furthermore the quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it [10].

Kombolcha is one of the industrial and a largest town in Ethiopia. Kombolcha is established since 1936 G.C which located 376km by road North East of Addis Ababa. Its geographical coordinates are approximately 11˚5'N latitude and 39˚44'E longitude. The town is found in an area of average altitude, of about 1842m and 1915m above sea level. It is a industrial town of the Amhara Region and is surrounded by South Wollo Zone. Nowadays in Kombolcha town there is a lot of civil works take place such as Hotels, Mixed used purpose building, Hospital, road, Universities, colleges, airport, school, industries etc. in order to perform such infrastructure there should be adequate construction materials available such as cement, coarse aggregate and fine aggregate etc. However, in kombolcha town there is sand availability natural river sand quality problem that used for different concrete works even though in order to continue the civil works most of the contractors use different types of sand from varies resource such as Kombolcha Above Borkena Bridge.

II. METHODOLOGY

The strength of a material is defined as the capability of the material to resist stress without failure [11]. The strength of hardened concrete is fundamental in structural design, and is widely used as an index to predict other concrete properties. All concrete is porous to some extent, primarily because of excess water in the concrete mix. More water is added to concrete than is necessary for hydration in order to achieve acceptable workability. It is this excess water that remains un-reacted in the concrete and results in pores. The interface between the aggregate and the concrete has been found to be the weakest area in the concrete matrix [11].

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. This inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including in ASTM C143 in the United States.

The sampling technique used for this research was a purposive Sampling technique which is the non-probability method. This sampling technique was proposed based on the information that the researchers have and the aim or goal of the researcher to be achieved. The independent variable of this research was Silt/clay content and gradation or particle size distribution of fine aggregate which the two parameters that determine the quality of the natural river sand. Both primary data sources and secondary data sources were used. Secondary data needed for this research was collected from different journals, book, website etc. during the literature review and primary sources of data for this study were a laboratory experimental output.

Type of Cement used in the concrete mix was Messobo-Ordinary Portland cement (OPC) having Cement Grade 42.5R. Crushed stone 25mm maximum Nominal size that was commonly used in Kombolcha Town. The sand was collected from Above Borkena Bridge found in Ethiopia. Drinkable water used of preparing mixture.

Concrete mixes, tow coarse aggregate5-15mm and 15-22mm or (0.1mm) and (0.2mm) YAPİ MERKEZİ Crusher Plant crushed stone was used.

All the river sand samples of each type was divided into two parts. The first part of the sand sample was washed with potable water by using 75μm sieve in order to free of clay/silt content and sun dried on a clean platform and the saturated surface of the dried sample checked using small cone and tamper. The second part of each sand samples used for both sand properties test and the original sand samples were used to prepare the concrete mix without washing the sand samples.

A test on coarse aggregate was conducted according to ASTM and BS Standard Procedures. (i.e. sieve analysis or gradation, water absorption, unit weight, specific gravity, moisture content). Similarly, test on fine aggregate was conducted according to ASTM and BS Standard Procedures. (i.e. sieve analysis or gradation, water absorption, unit weight, specific gravity, moisture content bulking of sand and Silt/Clay Test of Sand sample). A test on cement was conducted (i.e. Consistency test, initial and final setting time test and fineness of cement test). The Sand was graded in accordance with ASTM C 117. This method was used to determine the particle size distribution of the coarse and fine aggregate down to 75μm. The Sand Sample being graded was collected from the bag where it was being stored. This material was then dried in an oven at 110±5 C˚ for 24 hours to ensure it was dry.

This sand was weighed and then washed through a 75μm sieve, using potable tap water, prior to the sieve analysis so that the micro-fines content would not affect the results. The washed sample was then dried in the oven at 110±5C° for 24 hours and then weighed, as before. The mass of material passing the 75μm sieve and retained on the pan could now be calculated as the difference in dried mass before and after washing the sand.

The washed and dried sand sample was then sieved through a standard set of sieve sizes. Once the sand had been sieved, the mass of soil retained on each sieve could be measured. This allows for the cumulative mass of sand passing each sieve size to be calculated after that plot grading curve with the cumulative percentage of sand passing each sieve size against sieve size. The unit weight is simply measured by filling a container of known volume and weighing it.

Then, dividing the aggregate weight by the volume of the container provides the unit weight of the aggregate.

Since aggregates generally contain pores, both permeable and impermeable, the meaning of the term specific gravity has to be carefully defined, and there are indeed different types of specific gravity, like: apparent specific gravity and bulk specific gravity to saturated and surface dry (SSD). Bulk specific gravity refers to total volume of the solid including pores of the aggregate, and Apparent specific gravity refers to the volume of the solid is consider to include the impermeable pores but not the capillary ones whereas, absorption capacity of the aggregate is the ability of the aggregate to absorb the mixing water.

The moisture content of fine aggregate was determined by oven drying 500gm of fine aggregate (sand) for about 24hrs with a temperature of 105 °C to 110 °C and cooling for an hour. Then, dividing the weight difference by oven dry weight and multiplying by hundred provide the moisture content.

In this research work, the ACI Method of concrete mix design was used to design C-25 concrete grade having a 33.5 MPa target mean strength with 0.48 of water to cement ratio. In addition to this, the slump was 25 to 50mm. On this basis the mix design was prepared for the original sand samples used at kombolcha town Above Borkena Bridge. The quantity of concrete materials was calculated by using the physical properties of the materials. The standard cast plastic moulds of size 15cmx15cmx15cm were used in the preparation of concrete cubes for compressive strength tests.

The ingredients, such as; cement, fine aggregate (sand), coarse aggregate and water were measured to an accuracy of 0.1g. The weighted coarse aggregate was first added on the large flat plat and the fine aggregate was added after the coarse aggregate and then the cement is added next to fine aggregate and dry mixed for a minute. Then, water was added to the dry mixed concrete ingredients mixture and admixtures TC1500 thoroughly mixed for two more minute.

The mixed concrete was checked for workability by filling the standard slump cone with three layers by Roding each layer with 25 times according to ASTM C143.

After checking the slump the mixed concrete was placed in the mold and was well compacted in three layers with the help of a tape rode by rodding each layer with 25 times and as well as Side compaction of the molds was carried out by using tire hammer. After 7 and 28 days curing period the concrete cube specimens were removed from the water bath then placed in dry surface until the specimens were surface dried while weighted concrete cubes specimens in order to determine the unit weight of the concrete cube Finally, the specimens was tested by using “Wizaro Basic” a Digital readout ,Universal Testing Machine. Loading Rate for 150 mm cube was 140 kg/cm2 per minute till the Specimens fails.

(a) SSD cube samples	(b)Weighing of cube sample	(c) Compressive strength test

Figure 1 (a, b and c) shown in stage of compressive strength.

III. Results And Discussion

It was found that the sands exhibit a wide range of properties, with a wide range of grading characteristics and silt and clay contents. Silt/ Clay contain of the sands sample were identified for ABB sample have been identified. The sample of sand by investigating the influence that these sands have on concrete property, the key sand properties that have the greatest effect on the performance of concrete can be identified. Ordinary Portland Cement (OPC) Mesobo 42.5R Cement Grade was used throughout the experiment which is commercially available in kombolcha Town. The physical properties of cement are shown in Table 1.

Table 1: Physical properties of cement

Material	Type of Cement	Types of cement test	Test result
CEMENT	OPC (ORDINARY PORTLAND CEMENT)	Fineness of cement	95% passing
		Cement consistency test	
		W/C ratio (%)	32%
		Water(gm)	160
		Penetration (mm)	9.3
		Setting Time	
		Initial	1hr. 32min
		Final	4hr. 20min
		Specific gravity	3.15

The coarse aggregate used for this research was basaltic crushed rock from “DESSE (YAPİ MERKEZİ Crusher Plant)”.

The fine aggregate used in the concrete productions was natural river sands and they were dried to saturated and surface dry (SSD) state before any test was carried out. In addition to this, all fine aggregate which retain on 9.5mm sieve size were no longer relevant, and all the passing fine aggregates were used for experimentation. Then, the following tests were conducted for each source of fine aggregate.

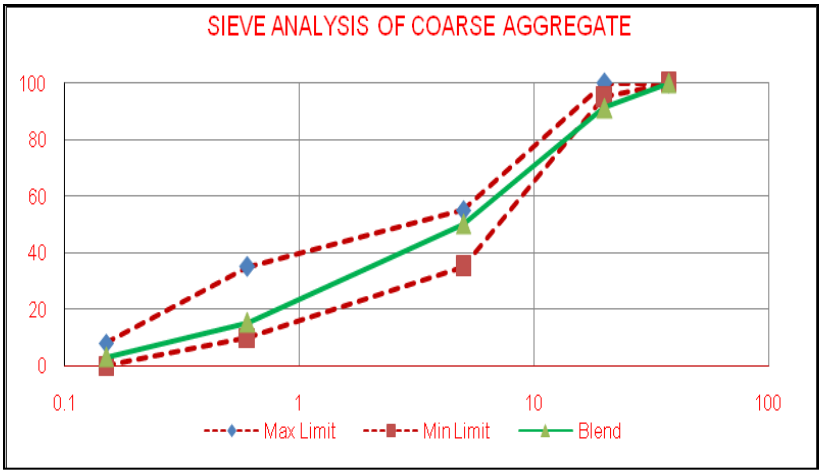

Figure 2 Sieve analysis of coarse aggregate

According to ASTM C33, the gradation result of the ABB sample was out of range on 4.75 mm and 2.36 mm sieve size on other hand based on BS 882 the sample was in satisfactory condition. The Sieve analysis of fine aggregate used for the experiment based on BS specification. The grading of the ABB original sand sample has Good under zone one which is Coarsest Sand [12]. Fineness Modules of the ABB sand sample is 5.432, this can be interpreted that the third sieve, i.e. 600µ m is the average size.

Table 2: Sieve analysis based on BS and ASTM grading requirements of fine aggregate ABB

Sieve Size mm	Weight retained gram	Passing %	ASTM Limits		BS limits	
			lower	upper	lower	upper
9.50	33.0	80.0	100	100	100	100
4.75	77.5	69.6	95	100	89	100
2.36	85.5	58.1	80	100	60	100
1.180	129.0	40.7	50	85	30	100
0.600	141.5	21.7	25	60	15	100
0.300	92.5	9.3	10	30	5	70
0.150	38.0	4.2	2	10	0	15
0.075	15.0	2.1	0	5		
PAN						

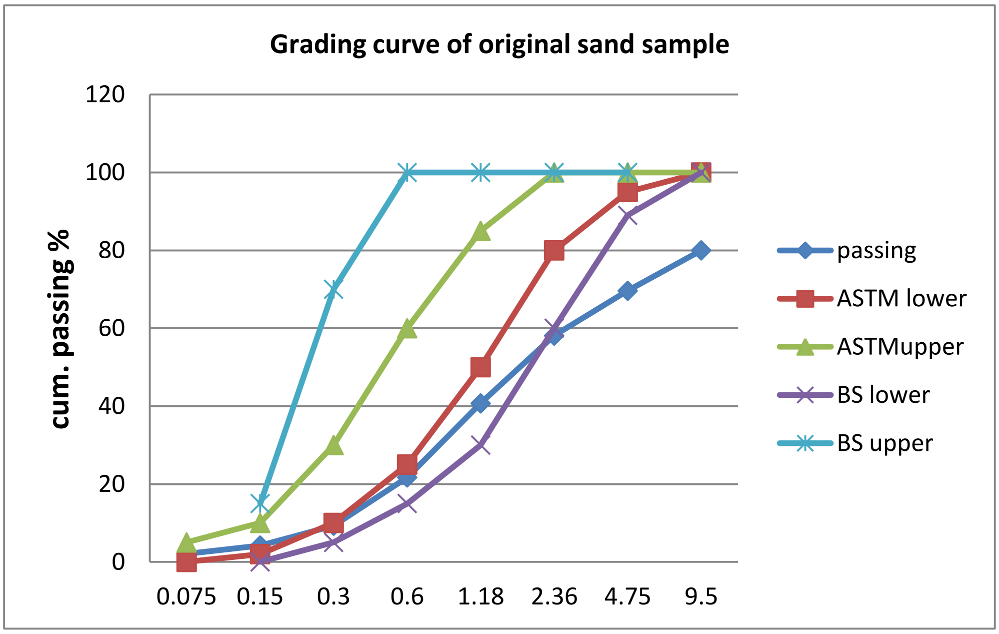

Figure 3. Sieve analysis of original sand sample ABB based on ASTEM and BS

Table 3: Zoning of ABB original sand

Sieve Size standard mm	Ave.cum Passing %	Percentage of passing							
		Zone 1		Zone 2		Zone 3		Zone 4	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
9.50	80.0	100	100	100	100	100	100	100	100
4.75	69.6	90	100	90	100	90	100	95	100
2.36	58.1	60	95	75	100	85	100	95	100
1.180	40.7	30	70	55	90	75	100	90	100
0.600	21.7	15	34	35	59	60	79	80	100
0.300	9.3	5	20	8	30	14	40	15	50
0.150	4.2	0	10	0	10	0	10	0	15
0.075	2.1					0	5		
PAN									

It is clear from the figure that a wide range of sand grading was used in the testing and all of the grading curves fall inside of the limits recommended by the BS 882, the ABB sand sample on sieve size 4.75mm and 2.36mm in addition to this, the sand sample including 0.3mm fall outside of the limits recommended by the ASTM C 33; While the sand sample on 1.18mm and 0.6mm fall outside of the limits recommended by the ASTM C 33.

The collected original sand samples have been washed as much as possible to minimize or eliminate the amount of silt/clay content in order to identify the effect of fine aggregate gradation on the compressive strength of concrete, for this reason the concrete cubes that made with the washed river fine aggregates that is ABB original sands the compressive strength at age of 7 day is 32.85MPa and 28 days is 45.92MPa.

In order to improve the quality of the sand sample washing was the best mechanism, in this way all sand samples have low Silt/Clay content and satisfy the requirement.

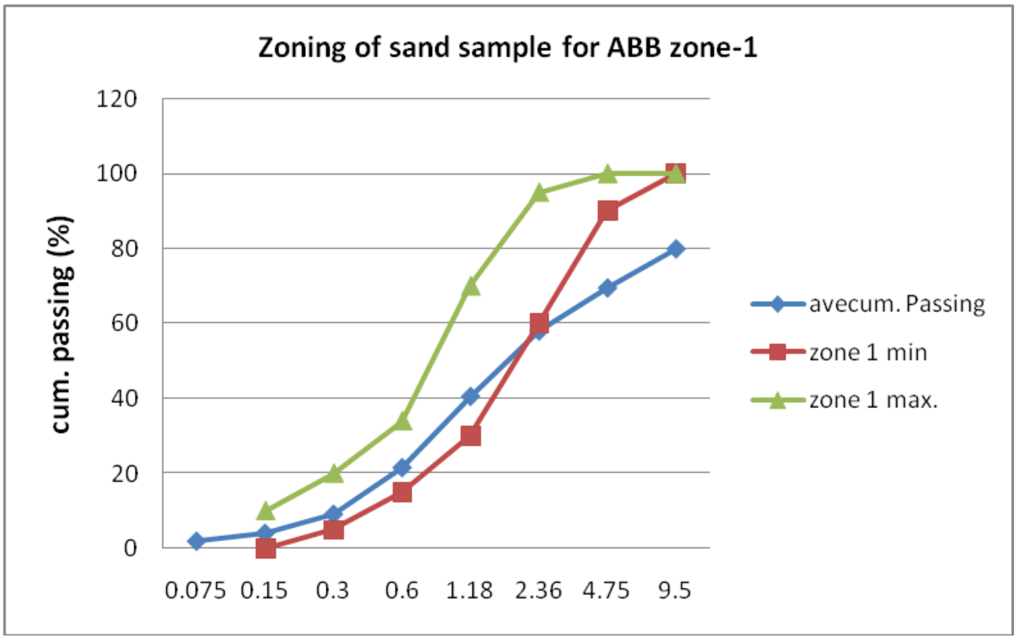

Figure 4. Zoning ABB original sand sample

A trend is apparent, where by low Silt/Clay aggregates produce relatively low strength concrete, intermittent Silt/Clay aggregates produce relatively high strength concretes and high Silt/Clay aggregates produce low strength concretes it is aggregate with [13].

However, the test results show that the entire sample cubes under satisfied condition. These indicate that up to 6% of silt/clay of the sand samples give more than the required strength.

Table 3: General properties of Natural River sand (fine aggregate) sample

Natural sand sample (fine aggregate	Properties of the sand sampling sand				Aveg. Slump test result (mm)	Aveg. Unit weight kg/m3 for 7 days	Aveg compressive strength for 7 day	Aveg. Unit weight kg/m3 for 28days	Aveg compressive strength for 28 day
	FM	Zone	Cu	Cc					
ABB	5.432	1	9.99	0.47	110	8172.33	32.85	8126.5	45.92

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IV. CONCLUSION

From the laboratory results the ABB sand sample had the compressive strength at age of 7days that is 32.85MPa and at age of 28 days 45.92 with 2.18% silt/clay content of 5.432, FM value and passing within zone I in sand classification. A slump value of 110mm which is low degree of workability and it is well graded (Cu=9.99) and poorly graded (Cc= 0.47). Therefore, the presence of silt/clay content within limit and well gradation of sand sample produced a better compressive strength as well as workability of concrete. Hence, it is recommended that natural river sand having low silt/clay content should be washed before use for concrete production.

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