Assessment of Quality of Sand Sources and the Effect on the Properties of Concrete (The Case of Bahir Dar and Its Vicinities)

Abel Fantahun[1(✉)] and Kassahun Admassu[2]

[1] Faculty of Civil and Water Resource Engineering, Bahir Dar Institute of Technology, Bahir Dar University, P.O. Box 26, Bahir Dar, Ethiopia
abelfantahun10@gmail.com

[2] Ethiopia Institute of Architecture, Building Construction and City Development, Addis Ababa University, P.O. Box 518, Addis Ababa, Ethiopia
kassahun.admassu@eiabc.edu.et

Abstract. The main purpose of this study is to assess the quality of sand sources, the effect on workability, compressive strength and cost of concrete in and around Bahir Dar. Initially, questionnaires and interviews were made with stakeholders and suppliers. After that, different natural sand samples were collected from 13 sand supply locations. Then, their physical and chemical properties were tested in laboratory. Finally, mix design is prepared for a normal strength concrete. From the survey results, it was found that, about 87.5% of the stakeholders use Arno, Tana, Tis-Abay, Addis-Zemen, Andasa and Rib as the major sand sources out of the thirteen around Bahir Dar and its vicinities. And about 67.5% of the stakeholders use more than one source. Trial mix designs were prepared for concrete production focusing on six of the common sources. The results have shown that, for normal strength concrete, the blended sand from six common sand sources met workability of the fresh concrete and there is no significant difference in compressive strength of concrete with blended sand. Finally, the finding has indicated that, all the thirteen supply locations have quality problems; especially in gradation as well as, in silt and clay contents. Based on the research outcome blending Addis-Zemen sand with that of Ribb sand incurs the least cost, while at the same time fulfilling requirements of fresh and hardened concrete.

Keywords: Concrete · Sand · Sand quality · Chemical composition · Workability · Compressive strength · Cost

1 Introduction

1.1 Background and Objectives

Concrete is one of the major construction materials in the building construction industry and it is produced from three basic ingredients; namely: cement, aggregates and water. In addition, admixture is sometimes used to improve some of the properties of concrete; like,

N. G. Habtu et al. (Eds.): ICAST 2019, LNICST 308, pp. 637–650, 2020.
https://doi.org/10.1007/978-3-030-43690-2_48

workability and setting time [1–3]. The ingredients of concrete should be of good quality that satisfies the requirements of set standards. It means that, 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 workability, strength and durability within a reasonable economy [3]. Quality of constituent materials used in the preparation of concrete plays a paramount role in the development of both physical and mechanical properties of the resultant concrete. Water, cement, fine aggregate, coarse aggregate and any admixtures used should be free from harmful impurities that negatively impact the properties of hardened concrete [1, 3, 5]. Quality control is a means of checking those concrete ingredients and production processes are in compliance with the requirements stated in codes of practices. It must be done by the contractor who fully takes the responsibility to ensure that the quality of materials and workmanship are as per the contract document. The quality control work undertaken by the contractor should be assured by the quality assuring agent, which is the consulting engineer. Use of poor-quality construction materials (such as sand, coarse aggregates or water) results in poor quality structures and may cause structural failures leading to injuries, deaths and loss of investment for developers [3, 5].

Fine and coarse aggregates make about 70% by volume of concrete production. It goes without saying that, the quality of concrete is thus strongly influenced by aggregate's physical and mechanical properties as well as chemical composition of the parent aggregate making material [4]. In keeping the quality of concrete in line with acceptable standards, one should concentrate in the properties of the concrete making materials. As a result, since sand is among these, it is obvious that it plays a critical role as a concrete ingredient and thus it deserves a special attention. The demand of natural sand is quite high in developing countries to satisfy the rapid infrastructure growth and the extensive use of concrete; which is causing a very high global consumption of natural sand. The situation of developing countries, like, Ethiopia is challenged by a shortage of good quality natural sand. Now a days, in Bahir Dar and its surroundings many construction projects are being carried out to a very large extent. As a result, the City of Bahir Dar is growing very rapidly. The blooming of construction projects in Bahir Dar City and its surroundings indicates the necessity of conducting performance tests on concrete and its constituent ingredients in order to assure money worth and safe construction works. The multi-faceted projects being constructed in and around the City are; various types of buildings, water supply, irrigation, roads and bridges. Considering all the above, the ever-increasing development of construction projects is becoming a cause for cost increase of construction materials as well as the frequent occurrence of disparity between supply and demand.

Riverbeds and lakeshores are the main sources of fine aggregate (sand) in and around Bahir Dar. So far, there is no clear information about the qualities of natural sand among stakeholders. It is also impossible to get identical construction materials even from a single day supply from venders, with regard to; sand gradation, clay and silt content and organic impurities, which are the prime determinants of workability and compressive strength of acceptable grade and good quality concrete.

Furthermore, there is an adversarial standardization among suppliers of sand, contractors, clients and professionals a like, in the construction industry due to the ambiguous quality of sand sources. If the properties of sand sources are known, engineers and professionals can select the nearby sources with possible remedial measures; such as, blending, washing, and screening for the intended purpose.

Thus, this research will focus on assessing the quality of sand sources and the effect on the properties of concrete, within Bahir Dar and its vicinities by conducting a questionnaire survey, interviews and laboratory investigations.

The general objective of the study is to assess the quality of sand sources in Bahir Dar and its vicinities and investigate the effect on the properties of concrete to be followed by discussions and recommendations in accordance with the outcomes of the findings.

2 Methodology

2.1 Survey on Selected Active (Under Construction) Projects and Interviews

Initially, questionnaires were developed for contractors, consultants and sand suppliers. The aim of taking a survey questionnaire and interview was in order to know the common sand sources and the awareness of stakeholders regarding quality of sand sources. Questionnaires were distributed to contractors who are working on active projects and dealing with $G + 5$ and above buildings. The research also employs laboratory investigation methods and procedures. Different natural sand samples were collected from 13 sand supply locations. Sand was collected from thirteen main sand supply locations in Bahir Dar City and its environs. Mostly, the sand sources are found in between Gondar and Bahir Dar located about 30–180 km North West of the Bahir Dar City and also along the route of Tissisat within a distance of 30–90 km south of the City. By name they are: Arno, Tana (Delgi), Arbaye, Keha (Ibnat), Addis Zemen, Ribb, Gumera, Hamusit, Lalibela, Andasa (Tule), Tis-Abay, Mendel (Gug) and Zema. From each source, representative sand samples were taken from riverbeds and banks. Sampling is done according to ASTM D75-87 [6]. From each supply point, a minimum of 100 kg of sand is bought for grading and producing concrete cubes. Eventually, laboratory tests were conducted on each source sand samples and their physical and chemical properties were checked to understand their compliance with set standards. Finally, after selecting the common sand sources and knowing the level of the fine aggregate quality from the test results mix design was prepared for normal concrete strength. For a C-25 mix, fine aggregate the natural sand sources of Arno, Tana, Tis-Abay, Addis Zemen, Andasa and Ribb were taken; after washing and blending to fulfill the requirements of ASTM. A mix for normal strength (C-25) concrete, which has a slump of 25–50 mm and a nominal maximum aggregate size of 19 mm, was prepared per ACI 211.1 mix design procedure.

2.2 Laboratory Procedure

After selecting the common sand sources and knowing the level of the fine aggregate quality from the test results mix design was prepared for normal concrete strength.

This is done, by using the same type of cement or Ordinary Portland Cement (OPC) grade 42.5, coarse aggregate and clean potable water. The schematic flow chart of Fig. 1 shows the methodology used in this research work.

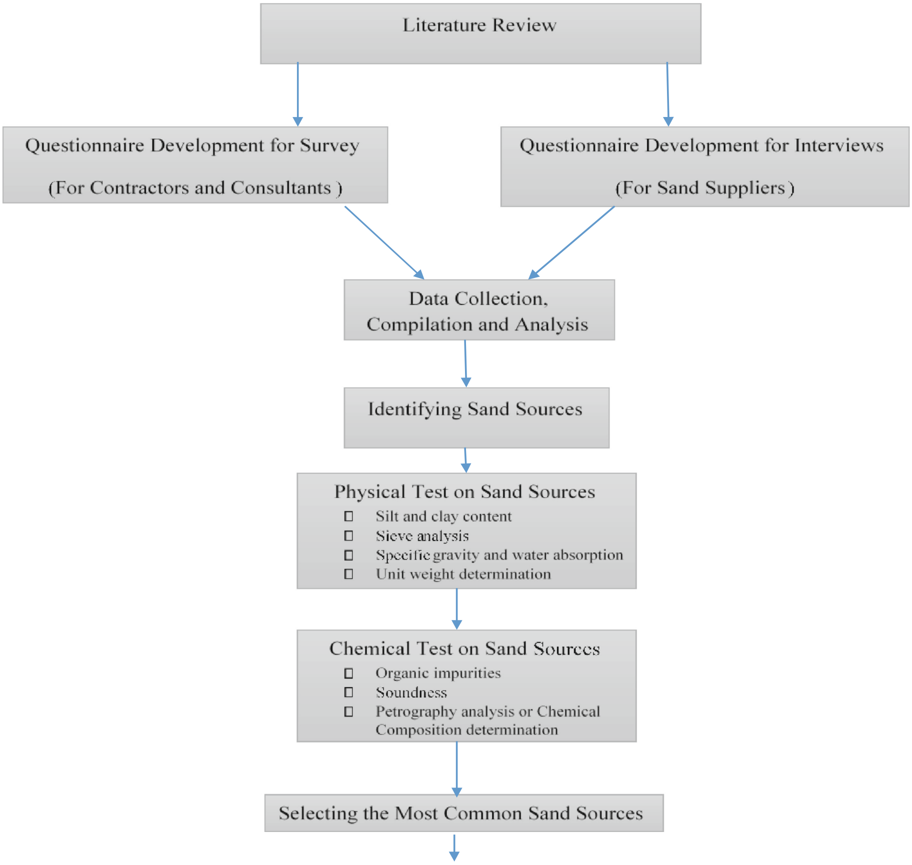

Fig. 1. Methodology flow chart

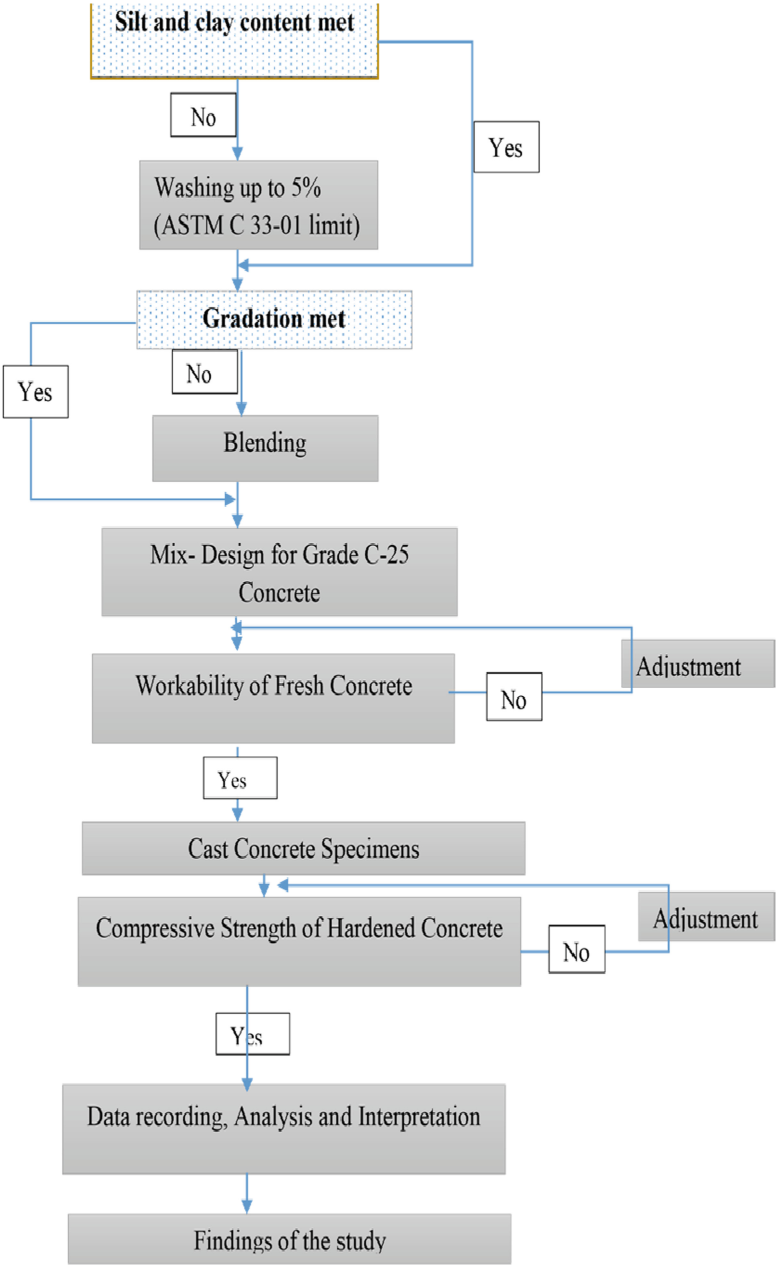

Fig. 1. (*continued*)

3 Results and Discussion

3.1 Acquisition of Data

Interviews were made with five sand suppliers working with different supply points mainly focusing on the major sources of fine aggregate for Bahir Dar City and its surroundings. According to suppliers, more than 13 sand sources are found in and around Bahir Dar. However, the sand that is supplied to customers do vary with seasonal variations, production methods, processes, and transportation cost. On the other hand, out of the 13 sand sources the most commonly purchased for concrete production are Arno, Addis Zemen, Ribb and Tana. Cost wise, those sands coming a far are expensive and are of good quality. The reason for this is transportation cost, in addition to their better quality and availability of sand. Of all the 13 sand sources those from Arbaye, Lalibela and Arno are costly.

The research appraised the major sources of fine aggregates for the construction industry of Bahir Dar and its environs. A total of 45 questionnaires were distributed to stakeholders out of whom 40 volunteers responded. This yields a response rate of

Table 1. Distribution of questionnaires and response rate

Respondent category	Questionnaires distributed (No.)	Questionnaires responded (No.)	Rate (%)	Valid responses (No.)	Valid responses (%)
Contractors	34	30	88.23	30	88.23
Site supervisors	11	10	90.91	10	90.91
Total	**45**	**40**	**88.88**	**40**	**88.88**

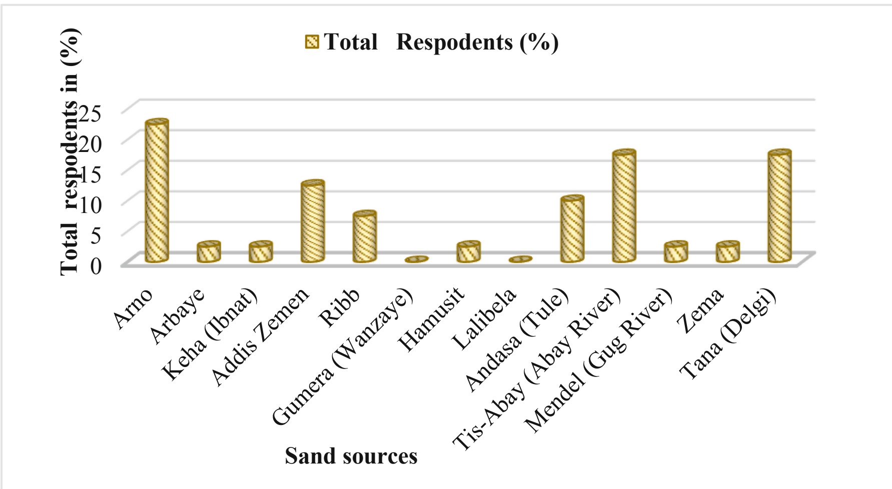

Fig. 2. Contractors' and site supervisors' responses on usage of sand sources

88.88%. Table 1 shows the number of questionnaires distributed to and collected from each respondent category.

Commonly used sand sources out of 13 are six and the cumulative of the six sand sources have 87.5% out of the total respondents as it is the shown in Fig. 2 above. Therefore, this shows that those six sand sources are significantly used by construction industry of Bahir Dar City and its environs. Sand used for concrete production is only from either one source or more than one for a single project. The assessment result shows, the 70% of the responded contractors use more than one sand source. In addition, among the responded site supervisors 60% of their supervising sites use more than one sand source. Totally 67.5% of the respondents replied that they use more than one sand source for concrete production. The result also shows, 90% of the responded contractors use natural sand for concrete production. The quality of the locally available fine aggregates is found to be unsatisfactory. Totally, 82.5% of the respondents replied that the quality of sand is not satisfactory. The result have shown that sieve analysis, silt and clay contents are the frequently conducted test for fine aggregate.

3.2 Laboratory Tests on Quality of Sand

The fine aggregate or sand samples were collected from 15th of October 2015 to 20th of December 2015. The test method used is ASTM C 136-01 [6, 7]. The fine aggregate gradation was within the limits of ASTM C33-01 or AASHTO M 6 and ES.C. D3.201 [4] is generally satisfactory for most concrete. A sieve analysis was conducted on samples collected from the 13 sand sources, the results of which were compared with those of applicable standards. From the results of the grain size analysis, it is observed that, all the common sand sources are more on the coarser side; except Ribb sand source. The gradation proportion for each blending batch was done with a minimum of ten trials (Table 2).

The results attained from this research have shown that 100% of the samples could not satisfy the set limits. As could be observed, 84.62% are more on the coarser side while 15.38% fall on to the finer sand. This has an implication that the fine aggregates supplied to the construction industry of Bahir Dar have problems as far as gradation requirements are concerned. The analysis of the sand sources have shown that, 53.85% of the samples have unacceptable fineness modulus value falling above the acceptable range and 46.5% complying with the Ethiopian Standard. Moreover, 76.93% of the sand sources have unacceptable fineness modulus value for mix design and 15.38% do comply with the requirements of ASTM C33-01. Regarding organic impurity, out of the 13 sand source samples tested, seven samples indicated lighter-straw and four colorless and two remained dark-straw than the standard solution in 24 h after mixing. This indicates that, 85% of the collected samples were within the organic content limit as set in AASHTO T 21-00, indicating a failure rate of 15%. Based on the 13 sand source samples tested, the maximum silt and clay content is 24.69% for TN (Tana) sample compared with the

Table 2. Summarized test results for the computation of sieve analysis of sand sources in percentage passing

Sieve size (mm)	AN (%)	TN (%)	TA (%)	AZ (%)	AD (%)	RB (%)	KH (%)	MD (%)	HM (%)	GM (%)	ZM (%)	AY (%)	LB (%)	AASHTO M6 (ES.C. D3.201) Limits (%)	
														Min	Max
9.5	92.8	98.3	91.3	88.3	90.2	98.7	94.8	97.8	94.3	99	93.7	94.6	99.5	100	100
4.75	73.0	92.6	77.1	75.4	80.8	96.4	87.4	92.7	84.3	97.3	86.1	90.5	97.4	95	100
2.36	48.2	76.7	61.7	65.3	64.7	94.1	73.2	82.1	67.0	95.1	78	83.2	91.1	80	100
1.18	31.1	58.9	49.0	56.2	48.1	91.9	54.6	65.8	48.8	92.7	68.7	70.5	78.8	50	85
0.6	13.9	21.7	21.3	33.2	23.2	85.3	22.8	24.9	17.2	67.7	41.0	33.4	40.9	25	60
0.3	4.3	1.1	1.7	7.5	6.4	16.8	5.5	2.8	2.5	7.4	6.6	9.4	7.2	10	30
0.15	1.0	0.2	0.1	1.1	1.4	1.7	0.9	0.3	0.4	0.9	0.7	2.3	0.8	2	10

minimum 4.83% for AY (Arbiya) sand sample by volume. In addition, 19.90% for HS (Hamusit) sample compared with the least of 1.70% of LB (Lalibela) sand sample by weight is quite large by any standard. ES.C. D3.201 recommends that, no more than a maximum of 6% by volume silt and clay content for fine aggregates be used in concrete production. Only one sand source out of the 13 met this limit, representing only 7.69%. An overwhelming percentage of 92.31 failed to meet the limit set in the Ethiopian Standard. Comparatively, this same Standard sets the allowable limit for silt and clay content in sand used for concrete production as 5% by weight. Only samples from three sources met this limit with a total of 33%, implying a failure rate of 77% of the tested sand samples per the quoted Ethiopian Standard. Surprisingly, only one source (AY), satisfied both by volume and by weight requirements for silt and clay content. The analysis of the samples shows 92.3% of the fine aggregates have loose unit weight whereas 76.9% have compacted unit weight values, which are not within the range stated in standard. Six major sand source samples were subjected to specific gravity test as detailed in ASTM C 128-01 for aggregates less than 10 mm diameter using the pycnometer glass vessel. Results have shown that, the bulk specific gravity in SSD lies between 2.44 and 2.66 while the water absorption is in the range of 1.66 to 2.92. As per the Ethiopian Standard requirement, the bulk specific gravity values lies between 2.4 and 3.0 for sand used in concrete production. This indicates that, the sand sources investigated are within the acceptable range for the production of structural concrete. Samples taken from the three sources and tested for soundness failed to satisfy the requirement. The values of the samples were too far above the maximum limit stated in standards. However, the good part of it is that, there is no ambient temperature variation and thermal energy difference in Bahir Dar City. The monthly maximum temperature difference is 16.2 °C and the annual variation of temperature ranges from 10.2 °C to 26.4 °C. That being the case, these aggregates might be used for concrete production.

The three sand sources (i.e. Arno, Tis-Abay and Tana) in and around Bahir Dar have a similar percentage of oxide composition. This implies that, the majorly sand sources have similar parent rock formation in their origin. On the other hand, they contain less SiO_2 concentration and have higher amount of Al_2O_3 and Fe_2O_3 as compared to sand from Dire Dawa sand, North Showa, Shoa Mugher sand, Tigray Adigrat sand and Tigray Sinkatta sand (Table 3).

Table 3. Comparison of three sand sources with different parent rock types in Ethiopia

Mineral oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O5	TiO_2	H_2O	LOI
Sample TA	46.72	17.09	11.26	6.00	3.24	3.16	1.48	0.1	1.45	7.31	1.14	2.50
Sample TN	48.30	20.16	8.10	9.54	2.98	2.12	0.42	0.18	0.23	2.69	1.56	4.71
Sample AN	46.50	16.78	12.20	7.96	4.5	2.34	0.72	0.16	0.57	4.24	1.50	3.71
Dire Dawa sand	75.89	13.14	0.83	2.00	0.03	3.70	4.02	0.02	0.01	0.05	Nil	0.99
Sand from north showa jema river valley	99.09	0.34	0.01	0.04	0.01	0.01	0.01	0.02	0.01	0.05	Nil	0.48
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
Shoa Mugher sand	96.1	1.91	0.32	0.1	0.1	0.1	0.1	Nil	Nil	Nil	Nil	0.49
Tigray Adigrat sand	99.5	0.27	0.04	<0.1	<0.1	<0.1	<0.1	<0.01	Nil	<0.02	–	0.24
Tigray Sinkatta	98.4–99.6	0.1–0.6	0.1–0.33	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Akaki olivine Basalt	47.0	15.70	14.8	8.0	5.6	3.4	0.9	0.2	0.7	1.1	3.3	Nil
*CEN Standard sand	99.5	0.15–0.30	0.015–0.03	0.03	0.005	BDL	BDL	BDL	BDL	0.016–0.04	–	BDL

It can be concluded that three sand sources are of similar oxide composition indicating a basaltic rock origin. However, the sand sources have lower silicon dioxide relative to CEN (Committee for European Norms) as standard sand.

3.3 Mix Design

From the trial mix results shown in Fig. 3 for a water cement ratio of 0.491 a maximum slump of 30 mm is observed, which is considered as of a low workability.

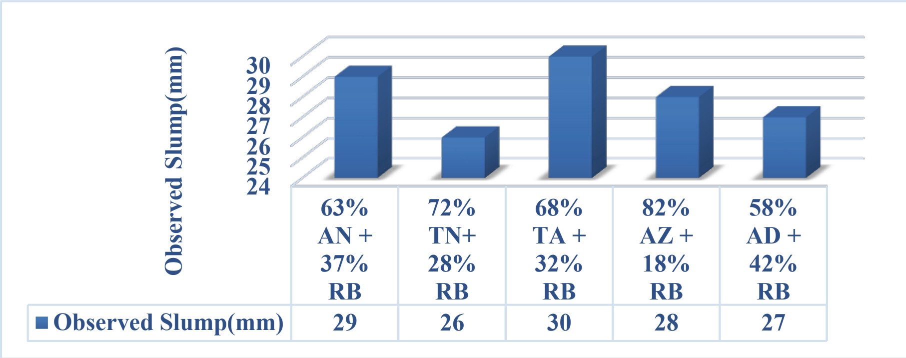

Fig. 3. Comparison of observed slump of the six blended sand sources

It is shown in Fig. 3 that, the observed slump of each blended sand from the different sources indicates no significant difference. This is due to similarity in their particle shape and surface texture. Even then, the observed slump of concrete mix with each blended sand proportions all fulfill the workability requirement of the mix, which is between 25- and 50-mm. Compressive strength of concrete specimens was determined by testing concrete cubes of 150 mm size. All specimens were weighed and measured to determine the density and the surface area of the cubes. The hardened properties of the concrete had been determined at the ages of 3, 7, 14 and 28 days. At each age, a minimum of three specimens were tested to ensure that the requirements of set standards are met.

It shown in Fig. 3 that, the different concrete mixes with five types of blended fine aggregates or sand proportions (i.e., 63%AN + 37%RB, 72%TN + 28%RB, 68%TA + 32%RB, 82%AZ + 18%RB and 58%AD + 42%RB) which impart a positive effect on the compressive strength of the produced concrete. The results are shown in Fig. 4 that, all the concrete mixes with different blending proportions have achieved the target mean strength, whereas, concrete mix proportions of 58%AD + 42% RB did not achieve the

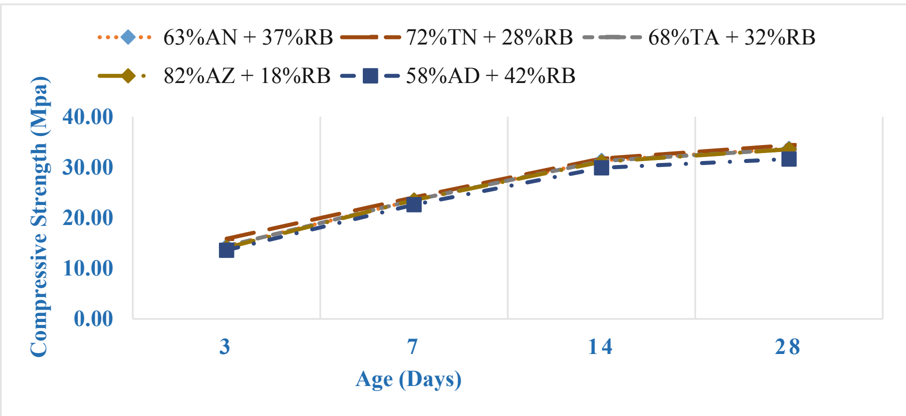

Fig. 4. Comparison of different concrete mixes with blended natural sand proportions

target: but has fulfilled the average compressive strength requirements. From this, we can conclude that using blended sand of the six available sources with specified proportions can improve the compressive strength of the produced concrete.

3.4 Cost Comparison of Concrete

The cost of concrete is assessed based on the material prices collected from most common coarse aggregate sources and cement suppliers within the City of Bahir Dar. Whereas, the price of sand is collected from six most common suppliers. These costs include both production and transportation as shown in Table 4.

Table 4. Cost of materials from different sources and suppliers

Ingredients	Cement (OPC 42.5 N) (Birr/Quintal)				Water (Birr/m^3)	
Source	Messebo	Derba		Dangote	Tap water	
Price	380	420		330	2.5	
Average	377				2.5	
Ingredients	Coarse aggregate (Birr/m^3)					
Source	Zenzelima	Bikolo		Kinbaba		
Price	575	555		525		
Average	552					
Ingredients	Natural sand (Birr/m^3)					
Source	Arno	Tana	Tis-Abay	Addis-Zemen	Andasa	Ribb
Price	556	450	510	480	470	490

Using the data of Table 4, a material cost for producing one cubic meter of concrete was calculated and the results are shown in Table 5 below.

Table 5 shows that, the cost of concrete differs from source to source with sand proportions. Moreover, from all the costs of concrete 82% Addis-Zemen with 18% Ribb natural sand proportion gives the lowest cost.

Table 5. Material and concrete cost per cubic meter of concrete for different proportions of blended natural sand

	Ingredients	Quantity (Kg/m^3)	Unit Price/kg	Price/m^3
63%AN + 37%RB	Cement	386.96	3.767	1457.5
	Natural sand Arno	486.93	0.311	151.3
	Natural sand Ribb	289.97	0.335	97.1
	Coarse Aggregate	1054.02	0.326	343.7
	Water	187.80	0.0025	0.5
	Total Price/m^3 of Concrete			2050.1
	Ingredients	Quantity (Kg/m^3)	Unit Price/kg	Price/m^3
72% TN + 28% RB	Cement	386.96	3.767	1457.5
	Natural sand Tana	534.08	0.294	157.3
	Natural sand Ribb	207.70	0.335	69.5
	Coarse Aggregate	1071.04	0.326	349.2
	Water	184.43	0.0025	0.5
	Total Price/m^3 of Concrete			2034.0
	Ingredients	Quantity (Kg/m^3)	Unit Price/kg	Price/m^3
68% TA + 32% RB	Cement	386.96	3.767	1457.5
	Natural sand Tis-Abay	523.04	0.284	148.5
	Natural Sand Ribb	246.13	0.335	82.4
	Coarse Aggregate	1064.19	0.326	347.0
	Water	187.46	0.0025	0.5
	Total Price/m^3 of Concrete			2035.9
	Ingredients	Quantity (Kg/m^3)	Unit Price/kg	Price/m^3
82% AZ + 18% RB	Cement	386.96	3.767	1457.5
	Natural sand Addis-Zemen	642.9	0.263	169.2
	Natural Sand Ribb	141.1	0.335	47.2
	Coarse Aggregate	1067.7	0.326	348.1
	Water	187.5	0.0025	0.5
	Total Price/m^3 of Concrete			2022.6
	Ingredients	Quantity (Kg/m^3)	Unit Price/kg	Price/m^3
58% AD + 42% RB	Cement	386.96	3.767	1457.5
	Natural sand Andasa	446.5	0.278	124.0
	Natural sand Ribb	323.3	0.335	108.2
	Coarse Aggregate	1059.1	0.326	345.3
	Water	187.0	0.0025	0.5
	Total Price/m^3 of Concrete			2035.6

4 Conclusion and Recommendation

From the survey results it was found that, the major source of natural fine aggregate are Arno, Tana, Tis Abay, Addis Zemen, Andasa and Ribb. Although there are several sand sources in the vicinity of Bahir Dar the contractors and consultants have no satisfaction on the availed quality of sand. As result of this, they use more than one source for concrete production. Though, stakeholders give little attention for sand quality tests, even then silt and clay contents and gradation tests relatively get a better attention. The sand test results have shown that, 100% of the sand sources could not satisfy the gradation requirements. 84.62% are more on coarser side and the rest on the finer side. However, the trail done on blending of the different sand sources have shown that gradation requirement can be achieved by blending the coarser sand with the finer one. The sand test result have shown that, sand directly taken from sources contain high silt and clay content and are not good in unit weight. In addition to this, the three top most common sand sources failed to satisfy the soundness requirements. However, 85% of the collected samples met the requirements of organic impurities, the six common sand sources samples met the specific gravity in SSD, and water absorption limits set in both AASHTO T 84 and Ethiopian standard. The three top most sand source have similar oxide compositions indicating a basaltic rock origin. However, they have lower silicon dioxide relative to standard sand. From this, it can be concluded that blending each source can have an advantages of; increasing the concentration of silica content which makes the sand to have more of sand stone properties rather than the basaltic one, reducing the amount of degraded sand and neglect of sand sources. This results in minimizing the environmental impact. As the cost analysis shows, using a blended sand in different proportions induces a variation in cost of concrete production. From all the produced concrete mixes, Addis Zemen with Ribb sand delivered the lowest cost of fresh concrete.

Based on the above conclusion the following recommendations are stipulated. Since stakeholders give little attention to sand quality, an awareness creation is of a prime importance. Sand users from the 13 sand sources are strongly advised to wash the sand before the production of concrete. Further investigation like, general evaluation on petrography of sand to assure quality against reactivity of aggregates is recommended. In order to get a concrete, which satisfies the fresh and hardened concrete requirements with least cost, it is better to use the blended sand from Addis Zemen and Ribb sources. Quarry sites should be checked periodically, by an independent body to enforce established quality assuring practices guided by set mandatory standards.

References

1. Kosmatka, S.H., Kerkhoff, B., Panarese, W.C.: Design and Control of Concrete Mixtures, 14th edn. Portland Cement Association, Skokie (2003)
2. Neville, A.M.: Properties of Concrete, 3rd edn. Longman Scientific & Technical, Harlow (1986)
3. Ngugi, H.N., Mutuku, R.N., Gariy, Z.A.: Effects of sand quality on compressive strength of concrete: a case of Nairobi county and its environs. Kenya. Open J. Civ. Eng. **4**, 255–273 (2014)
4. Dinku, A.: Construction Materials Laboratory Manual, vol. 1. Addis Ababa University Press, Addis Ababa (2002)

5. Dammo, M.N., Deborah, J.M., Aghidi, J., Isa, A., Falmata, A.K., Adams, K.: Effect of Ngala clay on the compressive strength of concrete. Int. J. Eng. Sci. Invention **3**(7), 07–10 (2014). ISSN (Online): 2319–6734, ISSN (Print): 2319–6726. www.ijesi.org
6. ACI 211.1-91, R.B.A.C. 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (1997)
7. ACI Education Bulletin E1-07: Aggregates for Concrete, Developed by ACI Committee E-701, Materials for Concrete Construction, August 2007