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The Impact of Aggregate Washing and Blending on Concrete Compressive

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ABSTRACT

The quality of constituent materials used in the production of concrete highly depends on physical and mechanical properties as well as the chemical composition of the parent aggregate-making material. At approximately 70 percent by volume, the aggregate takes up the largest part of the concrete production; for this reason, the quality of the ingredients used in the production of the concrete plays an important role and has a direct impact on the strength development of the concrete. In the Ethiopian construction industry, the aggregate used to make concrete does not meet the standard requirements. By standardizing the fine and coarse aggregates used for concrete production, the strength performance of concrete can be increased. The aim of this research work was to evaluate the influence of washing and blending aggregates on the concrete compressive strength of concrete. To achieve the research goal, the aggregates used to produce the concrete were collected, and laboratory tests were carried out on the aggregate samples and on the concrete mixtures. The findings showed that washing and mixing the aggregate improved the compressive strength of the concrete produced. For the controlled concrete mixes made with standardized aggregate by washed sands and blended aggregates, from 12.04% to 18.48%, 15.68% to 33.52% and 16.37% to 28.2% was an increase in compressive strength on the 3rd, 7th and 28th days, respectively, achieved for C25 concrete grade, and from 10.17% to 27.37%, 20.35% to 25.95% and 23.42% to 28.96% increases in compressive strength were obtained at the 3rd, 7th and 28th days, respectively, for C-30 concrete grade.

Key Words: Aggregate, Blending, Compressive Strength, Concrete, Washing

1. Introduction

Concrete is a mixture of water, cement, and aggregate, with the water and cement forming the paste and the aggregate serving as an inert filler. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water (Sidney et al., 2003). In absolute volume terms, the aggregate amounts to 65-75% of the volume of concrete (Abebe, 2002); this indicates that aggregate is the major constituent of concrete; hence, its properties have a significant influence on the engineering behavior of concrete. According to the research conducted by Ngugi (2014) in Kenya, the use of poor-quality construction materials (such as quality of sand, aggregates, or water) results in poor quality structures and may cause structures to fail to lead to injuries, deaths, and loss of investment for developers. Impurities in building sands contribute to reduced compressive strength. Olanitori (2006) asserts that the higher the percentage of clay and silt content in sand used in concrete production, the lower the compressive strength of the hardened concrete. It is a well-known fact that the compressive strength of concrete is influenced by factors such as the quality and proportion of fine and coarse aggregate, the cement paste, and the paste-aggregate bond characteristics; this demonstrates that the qualities of aggregates used in concrete production have a direct impact on the strength of the concrete because aggregate makes up the majority of the concrete. According to Denamo's research in Ethiopia, more than 44 percent of the coarse aggregate samples considered and 77 percent of the fine aggregate samples considered could not meet standard requirements. Studies conducted in various parts of Ethiopia have also shown that the naturally available material has 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 (Denamo, 2005); according to this study, the handling and quality controlling aspect of concrete making aggregates starting from the production process to storage and use in construction sites is very poor. Other research conducted in Ethiopia indicated that sand samples with a silt content as high as 20% are usually purchased from quarry sites in and around Addis Ababa (Abebe, 2005); this indicates that most of the fine and coarse aggregates used in the construction industry of Ethiopia are not standardized. Additionally, according to research conducted in Ethiopia, most sand sources are natural deposits or riverbeds(Gashahun, 2020), and the silt content is much higher than the standard. In most cases, sand with a higher silt content is directly used for making concrete, and even if washed, it is used for formality and not to meet the standard. That is why some Ethiopian contractors fail to make C-25 because of a lack of knowledge of how to handle aggregate, how to mix, and how to cure concrete. On the other hand, enforcing regulation and timely supervision is weak in the Ethiopian construction industry (Biruk 2014). On the other hand, the research conducted in Debre Markos and its vicinities, Ethiopia, indicates that fine aggregates should be properly washed before use since most of them contain silt, clay, mud and other impurities that hinder the process of bonding; the level of silt and clay content ranged from 5.53% to 12.18% for unwashed sand. An overwhelming 60% of the tested sand samples failed to meet the silt and clay content limits set out in ASTM limits (Abebe, 2020). Therefore, the aim of this research is to check the effect of blending and washing aggregates on the compressive strength of concrete produced.

2. Materials and Methods

The work presented in this paper describes an investigation into the effect of aggregate blending and washing on the compressive strength of concrete. The aggregate used in the tests was fine and coarse aggregate, both of which are used in the construction industry in and around Hawassa, Ethiopia, for concrete production. All laboratory tests for fine and coarse aggregates, as well as concretes, were performed at Hawassa University's Construction Materials Laboratory. The sources of fine and coarse aggregate samples, as well as their physical properties, are listed below.

2.1. Materials

The aggregates used in this study were among the commonly used aggregates in and around Hawassa city; the fine aggregates used were sourced from the Belate, Halaba and Hawassa Ayer Marfia areas, while the coarse aggregates were from the Hawassa Monopol area; the coarse aggregates had a maximum aggregate size of 20 mm (02). Portland pozzolana cement with a strength class of 32.5R was used for the concrete mix design, which is in accordance with the Ethiopian standard ES C. D 5.202. (1990). On the other hand, tap water from Hawassa University was used for all concrete mixing in the laboratory work throughout the study.

2.2. Methods

ACI method mix design was used to proportion the control mixes; the mix designs were carried out taking 25 MPa and 30 MPa as the required characteristic compressive strength. In general, the concrete mix prepared was two types, one with blended and washed aggregate samples, which were used as a control mix, and the other with unblended and unwashed aggregate samples, which were used as an uncontrolled mix. A total of 12 mix designs (six controlled and six uncontrolled) were produced, and for each mix design, nine cubes were cast. Finally, to check the effect of washing and blending of aggregate on concrete strength, compressive strength tests were conducted for concrete cubes after curing the cubes for 3 days, 7 days, and 28 days. All the concrete cubes were produced with a cubical mould having dimensions of 15 cm*15 cm*15 cm, and the rate of loading of the compression testing machine according to ASTM C-39 (2001) should be within 0.15 to 0.35 MPa/sec; therefore, the rate of loading used was 0.3 MPa/sec.

2.2.1. Property of aggregate used for concrete mix design

Properties of fine aggregates

Natural sands were used as fine aggregates (sand) in concrete production. Various tests were performed to investigate their properties for the required purpose, including sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content and silt content tests. The results are presented below in Tables 1 to 4.

Table 1: Physical Properties of Fine Aggregate

No.	Test Description		Test Result		
			Belate sand	**Halaba sand**	**Ayer marfia sand(Hawassa)**
1	Moisture Content (%)		3.52	3.84	4.27
2	Absorption Capacity (%)		3.7	4.9	5.4
3	Specific Gravity	Bulk	2.23	2.15	2.13
		Bulk (SSD)	2.31	2.25	2.24
		Apparent	2.43	2.4	2.4
4.	Silt content (%)	Unwashed sand	8.93	12.58	14.56
		Washed sand	2.78	3.07	3.6

- **Sieve Analysis and fineness modules of fine aggregate**

Sieve analysis is used to determine the grading of aggregates, and the fineness modulus is used as an index of the fineness or coarseness and uniformity of aggregates. According to the grading requirements of the Ethiopian standard (ES. C. D3. 201), the fineness modulus should not be less than 2.0 and more than 3.5 with a tolerance of ± 0.20. In this section, there are charts and tables that show the gradation of fine aggregates from the three sources; the result indicated that the fine aggregate samples from the three fine aggregate sources do not satisfy the requirement set in the Ethiopian standard. The gradation of fine aggregates is very important because it affects the paste requirement of concrete, workability of fresh concrete, and packing density and determines the economy of concrete production. In this section, the laboratory results of sieve analysis of blended and unblended fine aggregate samples are presented and discussed.

- **Sieve analysis of the Belate sand**

The sieve analysis result of Belate area sand shows that the sand sample is out of the limits specified in the Ethiopian Standard ES C.D3.201 (1990); the standard states the percentage passing for fine aggregate on sieve size 300 µm and 150 µm should be 10% - 30% and 2%-10%, respectively; but the Belate area sand gradation result showed that the sand sample is below the lower limits on sieve size 300 µm and 150 µm. To obtain the sand samples that fulfil the standard limits for fine aggregate gradation, I blended 80% of the sand particles passing through a sieve size of 9.5 mm and 20% of the sand particles passing through a sieve size of 600 µm, and the results in Table 3 were obtained, as shown in Table 2.

Table 2: Sieve analysis result of Belate sand

Size of Sieve (mm)	Percentage passing (ES C.D3.201)	Cumulative Passing of original sand) (%)	Percentage passing (Blended sand)
9.5	100	100.0	100.0
4.75	95-100	98.0	98.2
2.36	80-100	94.8	95.5
1.18	50-85	82.3	83.5
0.6	25-60	48.6	52.0
0.3	10-30	**9.0**	14.4
0.15	2-10	**0.6**	2.0
Pan			

- **Gradation chart of Belate sand**

A gradation chart is mainly useful for checking whether the results obtained from the sieve analysis of a given sample comply with the limits specified in the standards. The results obtained as percent passing or percent retained can be shown graphically in aggregate grading charts. On the gradation chart, the horizontal axis shows the sieve size opening, which is arranged in ascending order from the smaller to larger sieve openings. The vertical axis on the chart indicates the total percentage passing in ascending order from bottom to top.

The graph in Figure 1 below shows the gradation result of the original sand samples and blended sand sample of the Belate area sand.

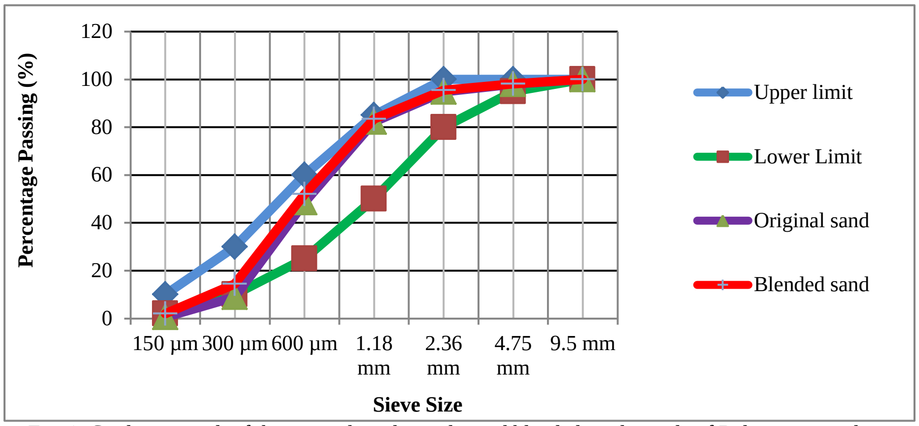


Fig. 1: Gradation result of the original sand samples and blended sand sample of Belate area sand.

- **Sieve analysis result of Halaba sand**

The Ethiopian Standard ES C.D3.201 (1990) states that the percentage passing for fine aggregates on a sieve size of 150 µm should be 2%-10%, but the Halaba area sand sieve analysis result shows that the sand sample percentage passing on a sieve size of 150 µm was 0.7, which is below the lower limits. To produce fine aggregates that fulfil the gradation requirements, the sand from the Halaba area was blended by combining 80% of the sand, which passes through a sieve size of 9.5 mm, and 20% of the sand, which passes through a sieve size of 600 µm; the results in Table 3 were obtained.

Table **3**: Sieve analysis result of Halaba sand

Size of Sieve (mm)	Percentage passing (ES C.D3.201)	Cumulative Passing of original sand) (%)	Percentage passing (Blended sand)
9.5	100	100.0	100.0
4.75	95-100	95.1	95.7
2.36	80-100	90.7	92.0
1.18	50-85	78.1	77.1
0.6	25-60	47.5	50.2
0.3	10-30	11.0	17.3
0.15	2-10	**0.7**	2.3
Pan			

The figure below shows the gradation chart of blended and unblended Halaba area sands.

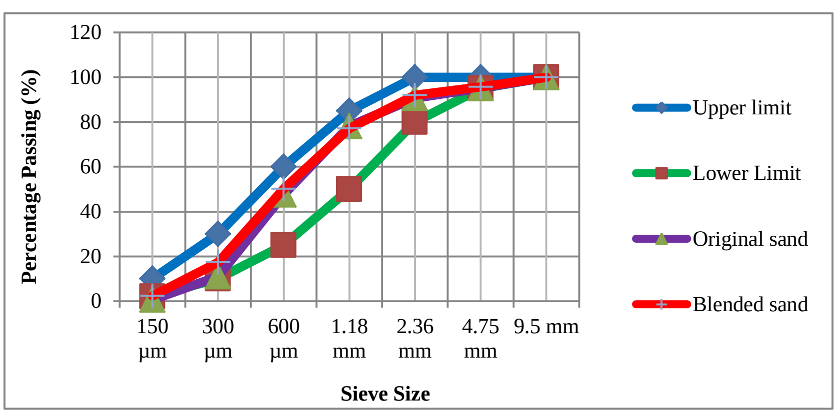


Fig. 2: Gradation result of the original sand samples and blended sand sample of Halaba area sand.

- **Sieve analysis result of Hawassa Ayer Marfia sand**

The sieve analysis result shows that the sand sample from the Hawassa Ayer Marfia area is out of the range specified in the Ethiopian Standard ES C.D3.201 (1990); in the standard, it is stated that the percentage passing for fine aggregates on sieve sizes of 300 µm and 150 µm should be 10% - 30% and 2%-10%, respectively. However, the Hawassa Ayer Marfia area sand gradation result showed that the percentage passing of sand samples was below the lower limits on the specified sieve sizes; the percentage passing was 6.6% and 0.3% on sieve sizes of 300 µm and 150 µm, respectively, and the fineness modulus value of the sand sample was 3.05, which indicates that the sand is coarser. To obtain sand samples that fulfil the gradation requirements specified in the standard blending of the sand was done in the same way as blending for Belate and Halaba sands. Hence, I blend 80% of the sand that passes a sieve size of 9.5 mm with 20% of the sand that passes a sieve no. 600 µm and obtain the results in Table 4.

Table **4**: Sieve analysis result of Hawassa Ayer Marfia sand

Size of Sieve (mm)	Percentage passing (ES C.D3.201)	Cumulative Passing of original sand) (%)	Percentage passing (Blended sand)
9.5	100	100.0	100.0
4.75	95-100	98.1	98.0
2.36	80-100	94.1	93.1
1.18	50-85	68.1	71.5
0.6	25-60	28.1	33.6
0.3	10-30	**6.6**	10.9
0.15	2-10	**0.3**	2.1
Pan			

The chart below shows the gradation of the Hawassa Ayer Marfia area sand sample.

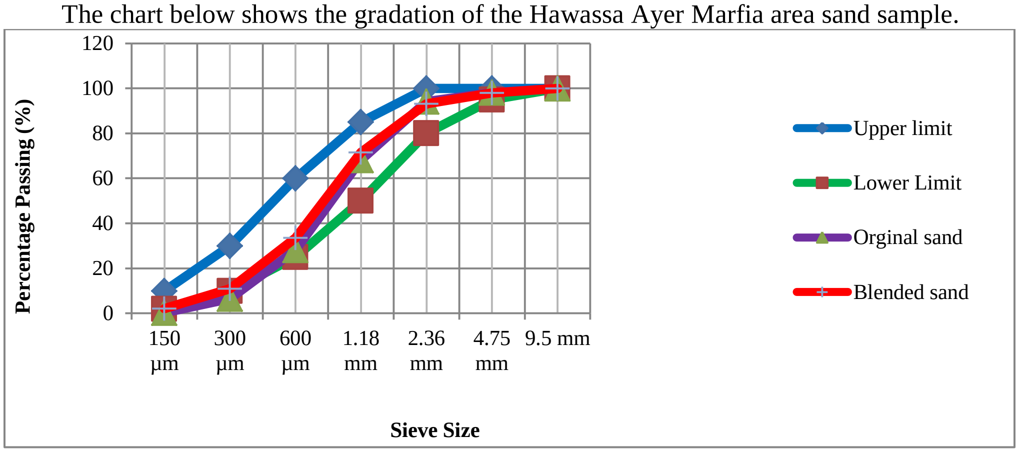


Fig. 3: Gradation chart of blended and unblended sand of Hawassa Ayer Marfia sand

Properties of coarse aggregate

In the same manner as the fine aggregate, before using the coarse aggregate for the required purpose, the property test was conducted. Various property tests were performed on coarse aggregates, including Sieve Analysis and Fineness Modulus, Specific Gravity and Absorbent Capacity, and Moisture Content. and unit weight tests. Table 5 below shows the results of the physical property of the coarse aggregate from the monopoly area.

Table **5**: Physical properties of the coarse aggregate

No.	Test Description		Monopol (Hawassa)
1	Moisture Content (%)		1.09
2	Absorption Capacity (%)		1.6
3	Unit Weight (g/cm3)		1.524
4	Specific Gravity	Bulk	2.55
		Bulk (SSD)	2.59
		Apparent	2.66

❖ Sieve Analysis of coarse aggregate

In the same way as the sieve analysis for the sand samples, the sieve analysis for the coarse aggregate sample was conducted according to the Ethiopian Standard ES C.D3.201 (1990). The table below shows the sieve analysis result of Monopol area coarse aggregate samples; as can be observed from the result, the aggregate samples are out of the limits specified in the standard on sieve sizes of 19 mm and 9.5 mm; the allowable limits in these sieves according to the standard are 95% to 100% and 25% to 55% for the specified sieve sizes, respectively. However, for the unblended Monopol area, the coarse aggregate percentage passing in the sieves was 67.8% and 7.8% for sieve sizes of 19 mm and 9.5 mm, respectively, as shown in Table 6; this indicated that the Monopol area coarse aggregate sample was coarser.

To obtain coarse aggregate that meets the requirements in the standard, coarse aggregate blending was performed. As a result of separate sieving of the coarse aggregate sample, 80% of coarse aggregates that pass through a 19 mm sieve opening were blended with 20% of aggregates with a maximum size of 10 mm (01) aggregates, yielding the results shown in Table 6 below.

Table **6**: Sieve Analysis result of Monopol area coarse aggregate

Size of Sieve (mm)	Percentage passing (ES C.D3.201)	Cumulative Passing of original sand) (%)	Percentage passing (Blended sand)
37.5	100	100.0	100.0
19	95-100	**67.8**	100.0
12.5	-	33.9	59.3
9.5	25-55	**7.8**	35.2
4.75	0-10	0.6	0.5
Pan			

- **Blending of Monopol area coarse aggregate samples**

The figure below shows the gradation chart of the original and blended samples of Monopol area coarse aggregate. As shown in Figure 4, the blended coarse aggregate sample is within the allowable range in the Ethiopian standard ES C.D3.201.

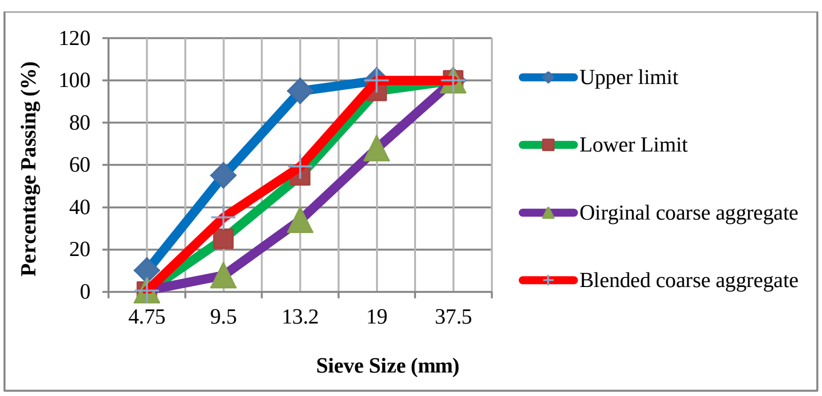


Fig. 4: Gradation chart of the original sample and blended coarse aggregate of Monopol area coarse aggregate

2.2 Concrete Mix Design

The table below shows the mix design result of the materials required for controlling the concrete mix.

Table **7**: Mix design for the control mix

For C-25 concrete grade				
Mix code	Materials			
	Cement (kg)	Water(kg)	Fine aggregate (kg)	Coarse aggregate(kg)
MMB	328	197	742	1002
MMH	328	203	725	986
MMA	328	204	771	940
For C-30 concrete grade				
MMB	373	197	694	1002
MMH	373	202	701	971
MMA	373	203	724	940

Remark: MMB; Mix of Monopol coarse aggregate and Belate fine aggregate
MMH: Mix of Monopol coarse aggregate and Halaba fine aggregate
MMH: Mix of Monopol coarse aggregate and Ayer marfia fine aggregate

Uncontrolled mixes were prepared by keeping the above mix proportion constant. Six mixes were made by using the same sources of fine aggregate and coarse aggregate in the same way as a control but without washing and blending of the aggregates.

Table 9 below shows the mean compressive strength results of the controlled and uncontrolled concrete mixes prepared in the laboratory.

Table **8**: Mean compressive strength of the concrete

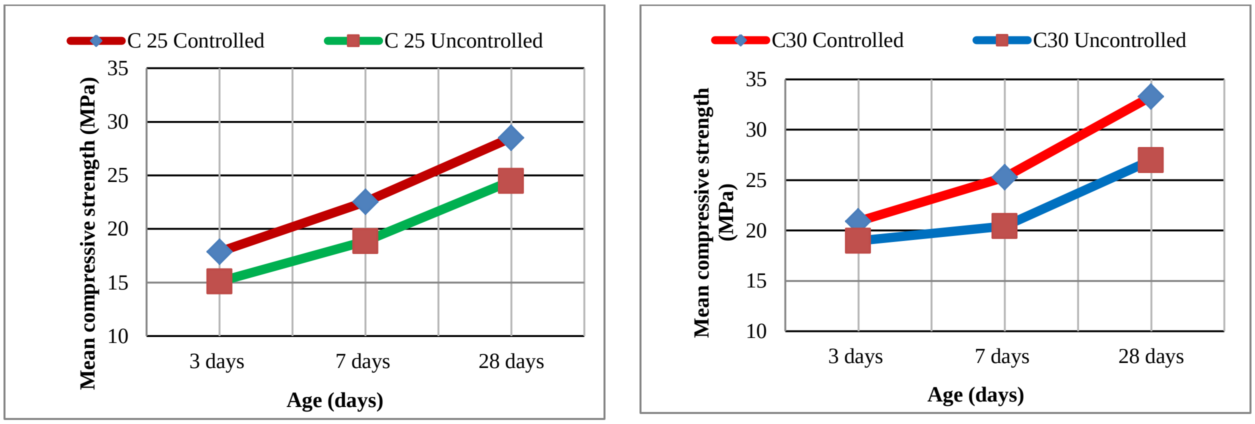
Controlled Mix						
Age of strength development (days)	**Mean Compressive Strength**					
	Mix Code					
	MMB		**MMH**		**MMA**	
	C-25	**C -30**	**C-25**	**C -30**	**C-25**	**C -30**
3 days	17.89	20.9	16.14	20.57	15.45	18.88
7 days	22.55	25.3	21.23	22.52	18.0	21.17
28 days	28.5	33.3	28.3	32.45	26.96	31.66
Uncontrolled Mix						
3 days	15.1	18.97	13.62	16.15	13.79	15.73
7 days	18.87	20.45	15.9	17.88	15.56	17.59
28 days	24.49	26.98	22.76	25.77	21.03	24.55

The table below shows the compressive strength development of controlled and uncontrolled MMB mixes. The percent increase in compressive strength for the C-25 grade MMB mix was 18.48%, 19.5% and 16.37% at the 3^{rd}, 7^{th} and 28^{th} days of age of concrete, respectively, whereas for the C-30 grade concrete, the percent increase was 10.17%, 23.72%, and 23.42% at the 3^{rd}, 7^{th} and 28^{th} days of age of concrete, respectively. For both concrete grades, the percentage increase is positive. This indicated that by washing and blending the aggregate, the concrete compressive strength can be improved. The percentage increase in compressive strength, which ranges from 10.17% to 23.72%, was obtained for both grades of concrete, as indicated in Table 10.

Table 9: Comparison of the strength development between the control and uncontrolled MMB mix.

MMB mix				
For C-25 MPa				
Age of strength development (days)	Controlled mix	Uncontrolled mix	Differences in compressive strength	% increases in compressive strength
3 days	17.89	15.1	2.79	18.48
7 days	22.55	18.87	3.68	19.5
28 days	28.5	24.49	4.01	16.37
For C-30 MPa				
3 days	20.9	18.97	1.93	10.17
7 days	25.3	20.45	4.85	23.72
28 days	33.3	26.98	6.32	23.42

The chart below shows the compressive strength development of the MMB mix for the C-25 MPa and C-30 MPa grades of concrete compressive strength.



(a) Compressive strength development of C-25 MPa grade of concrete (b) Compressive strength development of C-30 MPa grade of concrete

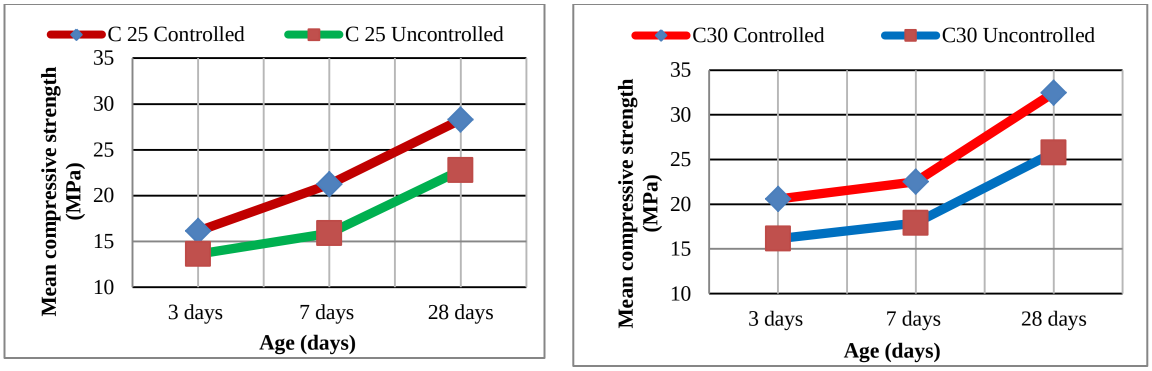
Fig. 5: Chart showing the compressive strength development of the MMB mix

Table 10 below shows the compressive strength difference between the controlled and uncontrolled MMH mixes for the C-25 and C-30 grades of concrete. The percentage increase in compressive strength for the C-25 grade MMH mix was 18.5%, 33.52%, and 24.24% for the 3rd, 7th, and 28th days of concrete, respectively; on the other hand, for the C-30 grade concrete, the percentage increase was 27.37%, 25.95%, and 25.92% for the 3rd, 7th, and 28th days of concrete, respectively. For both C-25 and C-30 concrete grades, the percentage increase was positive. This indicated that by washing and blending the aggregate, the concrete compressive strength can be improved. For the C-25 and C-30 concrete grades, the percentage increase in compressive strength ranged from 18.5% to 33.52%.

Table **10**: Comparison of the strength development between the control and uncontrolled MMH mix.

MMH mix				
For C-25 MPa				
Age of strength development (days)	Controlled mix	Uncontrolled mix	Differences in compressive strength	% increases in compressive strength
3 days	16.14	13.62	2.52	18.5
7 days	21.23	15.9	5.33	33.52
28 days	28.3	22.76	5.54	24.34
For C-30 MPa				
3 days	20.57	16.15	4.42	27.37
7 days	22.52	17.88	4.64	25.95
28 days	32.45	25.77	6.68	25.92

The chart in Figure 6 below shows the compressive strength development of the MMH mix for the C-25 MPa and C-30 MPa grades of concrete compressive strength.



(a) Compressive strength development of C-25 MPa grade of concrete

(b) Compressive strength development of C-30 MPa grade of concrete

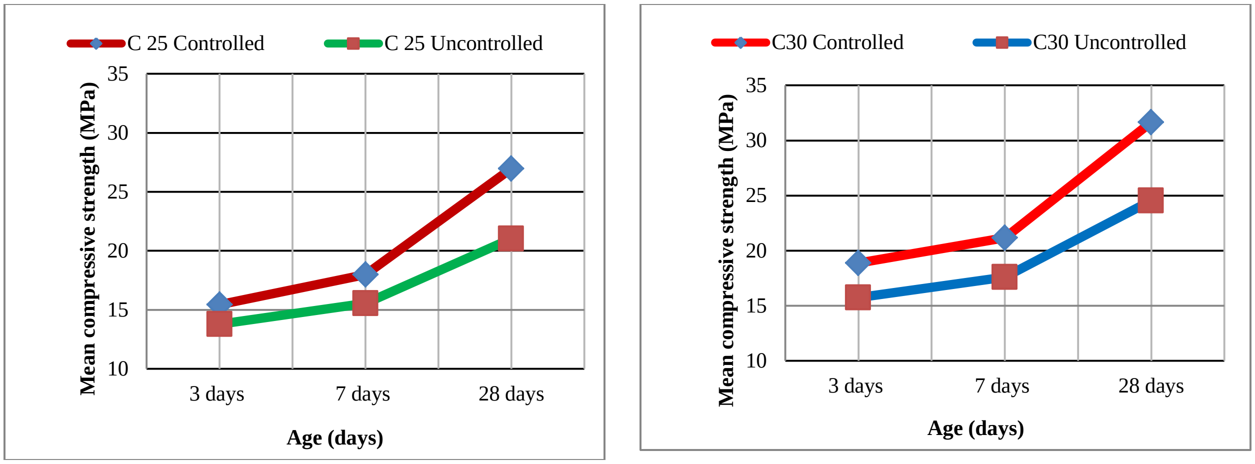
Fig. 6: Chart showing the compressive strength development of the MMH mix

In Table 11, the percentage increase in strength is indicated; the compressive strength difference between the controlled and uncontrolled MMA mix for C-25 and C-30 grades of concrete. The percent increase in compressive strength for the C-25 grade MMA mix was 12.04%, 15.68% and 28.2% for the 3rd, 7th and 28th days of concrete, respectively. On the other hand, for C-30 grade concrete, the percentage increase in compressive strength was 20.03%, 20.35% and 28.96% for the 3rd, 7th and 28th days, respectively. For both C-25 and C-30 concrete grades, the percentage increase was positive. The results showed that by washing and blending the aggregate, the concrete compressive strength can be improved. A percentage increase in compressive strength, which ranges from 12.04% to 28.96%, was obtained for C-25 and C-30 grade concrete.

Table 1**1**: Comparison of the strength development between the control and uncontrolled MMA mix.

MMA mix				
For C-25 MPa				
Age of strength development (days)	Controlled mix	Uncontrolled mix	Differences in compressive strength	% increases in compressive strength
3 days	15.45	13.79	1.66	12.04
7 days	18.0	15.56	2.44	15.68
28 days	26.96	21.03	5.93	28.2
For C-30 MPa				
3 days	18.88	15.73	3.15	20.03
7 days	21.17	17.59	3.58	20.35
28 days	31.66	24.55	7.11	28.96

The chart shown in Figure 7 represents the compressive strength development of the MMA mix for the C-25 MPa and C-30 MPa grades of concrete compressive strength.



(a) Compressive strength development of C-25 MPa grade of concrete (b) Compressive strength development of C-30 MPa grade of concrete

Fig. 7: Chart showing the strength development of the MMA concrete mix

In general, the effect of aggregate standardization was only tested in this study by washing the sand and blending fine and coarse aggregates; no other factors were considered. The benefit of sand washing was that it reduced silt content. This is because silts weaken the bond between the aggregate and cement paste and absorb a portion of the water required for cement hydration. As a result, the compressive strength and workability of concrete are reduced. In addition, blending of aggregate was performed since grading of aggregate is very important and can affect the paste requirement of concrete, workability of fresh concrete, and packing density and determine the economy of concrete production. As can be observed from the result for the three different mixes, which were prepared with unwashed sand and unblended aggregate for C-25 MPa and C-30 MPa grade of concrete, the compressive strength result failed for all three mixes. Hence, by blending and washing the aggregate, improved concrete compressive strength can be obtained, as indicated in the above tables and figures for a controlled concrete mix of MMB, MMH and MMA, and the result obtained confirmed with the result of Biruk (2014) that he achieved the required compressive strengths by standardizing the aggregate.

3.Conclusions

Standardizing aggregates by washing and blending can improve the compressive strength of the concrete produced while also lowering the additional cost of producing the required concrete grade by reducing the amount of cement used. In this study, the compressive strength of the concrete was increased solely by blending and washing the aggregate while keeping all other variables constant. For the controlled concrete mixes made with standardized aggregate by washed sands and blended sands and coarse aggregates, an increase in compressive strength of 12.04% to 18.48%, 15.68% to 33.52%, and 16.37% to 28.2% was obtained at the 3rd, 7th, and 28th days for C-25 grade of concrete; an increase in compressive strength of 10.17% to 27.37%, 20.35% to 25.95%, and 23. A 0.42% to 28.96% increase in compressive strength was obtained at the 3rd, 7th and 28th days, respectively, for the C-30 concrete grade.

According to the findings of this study, washing and blending have a positive impact on the compressive strength development of concrete. As a result, before using aggregate for concrete production, the property of the aggregate should be checked on a regular basis by the responsible body based on the requirement and condition of the materials, as well as when new materials are delivered to the construction site and the source of the aggregates is changed. Furthermore, aggregates used in concrete construction should be standardized. Standardization requirements should be imposed by responsible statutory bodies on parties producing fine and coarse aggregates, and quarry sites should be checked on a regular basis to ensure compliance with the standards.

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REFERENCES

Abebe Demisew. 2020. Investigating sand quality effect on concrete strength: a case of Debre Markos and its vicinities, International Journal of Construction Management, p 10.

Abebe Dinku. 2002. Construction Materials Laboratory Manual, Addis Ababa University press, 106 p.

Abebe Dinku. 2005. The Need for Standardization of Aggregates for Concrete Production in Ethiopian Construction Industry, Aggregate Conference, 16 p.

ACI 211.1-91. 2002. Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, Reported by ACI Committee 211, Farmington Hills, 38 p.

ACI 221R-96. 1997. Guide for Use of Normal Weight and Heavyweight Aggregates in Concrete, Reported by ACI Committee 221, 29 p.

ACI Education Bulletin E1-99. 1999. Aggregates for Concrete. Developed by ACI Committee E-701, pp. 1-26.

ASTM C 39. 2001. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, 5 p.

Biruk Negash. 2014. The Importance of Standardization of Aggregate in Ethiopian Construction Industry. M.Sc. Thesis. Addis Ababa University School of Graduate Studies, p 76.

Denamo Addissie. 2005. Handling of Concrete Making Materials in the Ethiopian Construction Industry, M.Sc. thesis, Addis Ababa university school of graduate studies, 166 p.

Ethiopian standards ES C. D3. 201. 1990. Aggregates, Normal Concrete Aggregates, pp.567-575.

Ethiopian Standards, Cement and Cement Products ES C. D 5.202,1990. Portland- pozzolane cement general requirements pp.605-66

Ethiopian standards ES 1177-1. 2005. Composition, specifications and conformity criteria for common cements, 2005, 26 p.

Gashahun, A. D. (2020). Investigating sand quality effect on concrete strength: A case of Debre Markos and its vicinities. International Journal of Construction Management, 0(0), 1–9. https://doi.org/10.1080/15623599.2020.1774838

Ngugi, H.N., Mutuku, R.N. and Gariy, Z.A. (2014) Effects of Sand Quality on Compressive Strength of Concrete: A Case of Nairobi County and Its Environs, Kenya. Open Journal of Civil Engineering, 4, 255-273.

Olanitori, L.M. (2006) Mitigating the Effect of Clay Content of Sand on Concrete Strength. 31st Conference on Our World in Concrete & Structures, Singapore, 16-17 August 2006.

Sidney Mindess, Francis J. Young and Darwin David. 2003. Concrete, second edition. Pearson Education, Inc.: United States of America, 644 p.

Neville, A. M. 2011. Properties of Concrete. Fifth edition. Pearson Education Limited, England, 709 p.