Investigation on Redefining the Silt Content of Sand in Concrete Production

Addisu Embaye
School of Civil Engineering, Ethiopian Institute of Technology-Mekelle, Mekelle University, P.O.Box 231, Mekelle, Ethiopia

Zenagebriel Gebremedhn (Corresponding author)
School of Civil Engineering, Ethiopian Institute of Technology-Mekelle, Mekelle University, P.O.Box 231, Mekelle, Ethiopia, Email: zencheboy@gmail.com

Abstract
This study investigates redefining the silt content of sand in concrete production. Fine aggregate has properties that differ from natural sands; for this reason, the plastic and hardened properties of concrete produced using manufactured fine aggregate differ from the properties of concrete made with natural sands. In most current standards used for construction purposes, the fines or material passing the N200 sieve content limitations have been intended for natural sands. Even though there are standards that have tried to stipulate for manufactured fine aggregate, the limits allow small amounts. The manufactured fine aggregate producers have faced difficulty meeting the standards specification and washing aggregate to lower silt content. This results in incrementing costs and develops environmental issues. The high proportion of silt fines found in the manufactured sand has been investigated in this research and the impact of the material on the properties of concrete both in fresh and hardened state. Thus concrete specimens with a w/c ratio of 0.58, 0.54, and 0.45 with different silt content of fine aggregate, ranging from 0% to 15%, were cast and tested on the Normal Strength Concrete, Intermediate Strength Concrete, and High Strength Concrete. Finally, the results of the tests have shown that better workability and better strength can be achieved with a concrete mix of up to 15 % silt content. The first trial faces workability and finishable difficulties. This was adjusted with a fairly increased water-cement ratio instead of using chemical solutions.
Keywords: Concrete production, Manufactured fine aggregate, Redefining silt content
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1. Introduction

Natural sand has been the major source of fine aggregate for concrete production exclusively. Due to the rise in demand for fine aggregate in the construction industry throughout the globe natural sand has become diminishing. Research has shown that the production of natural sand is characterized by high transportation costs since the available source is mostly far from the construction site. Unreliable or inconsistent supply of material both in quality and in quantity. The major source of natural sand is rivers, resulting in seasonal production due to high runoff during rainy seasons. Thus it is difficult to meet the demand during the rainy seasons. Technically undeveloped, produced, and supplied through manual techniques that are not mechanized and affect both quality and quantity, mostly exercised in Ethiopia (1, 2).

The production of good concrete as it costs little more than poor concrete is dependent mainly on the quality of its constituent materials. Aggregates were first considered as simply a filler for concrete to reduce the cement amount and it is the lion's share of the total volume of concrete-making materials. Unlike water and cement, which do not alter in any particular characteristic except in the quantity, in which they are used, the aggregate component is infinitely variable in terms of shape and grading. Therefore care must be taken in the production and supply of aggregate which has a significant role in the plastic and hardened state properties of concrete (3, 4).

Aggregates are end products for aggregate producers and are raw materials for concrete manufacturers. The quality of aggregate production is greatly influenced by its parent gravel or rock and cannot alter the characteristics during the production process. The produced aggregate may not necessarily have the properties of its parent rock or material, however, the quality of the aggregate can be enhanced at the stage of production using different techniques (5).

The other important factor in concrete production is the consistent supply of coarse and fine aggregates. In Ethiopia, coarse aggregate is produced by crushing basaltic stone, and river sand is the major natural resource for fine aggregate. Due to the rapid development of the construction industry in the four directions of the country, there is a scarcity and price increase of natural sand. And also characterized by its impact on the environment which is attributed to the non-renewable, land use conflicts, high energy consumption, and health impact. Therefore, due to the above drawbacks to using natural sand the construction industry has been to find viable solutions to offer the fine aggregate constituent for concrete production (6).

Manufacture sand has become a viable alternative material for natural sand. Manufactured sands are made by crushing aggregates to a size of less than 5.0 mm. The history of using manufactured aggregates (crushed hard rock) in concrete has started since the Romans (7, 8).

Ethiopia has been abundantly supplied with natural aggregate resources for construction purposes due to the geographical features of the country. Locally most concrete aggregates have been produced based on glacial-fluvial sand or gravel deposits, which are rich but unevenly distributed throughout the country and characterized by large transport distances. Thus the production of concrete has become expensive and has been facing difficulties while transporting from long distances such as time lag or delay supplying in the required amount. The use of manufactured sand for concrete production in Ethiopia started about a decade ago. This material is being used by foreign contractors for Asphalt and road structures (9, 10).

Even though sufficient quantities of gravel and natural sand are available in some parts of the country, concrete made with crushed aggregate sand is preferred for the production of concrete due to its superior performance when conditions require large quantities of high-quality aggregate and sand (11, 12).

The basic and significant differences between natural sands and manufactured sands result from the geological processes of shaping and sorting that have occurred in most natural sands. The individual grains in natural sands tend to be rounded to surrounded and have a smooth surface texture. If they are more mature sediments that are further from the source of erosion. They will tend to be better sorted, to the point with dune sands that they tend to approach single-sized materials. Most natural sands have been abraded to the point that weaker deposits. Minerals with clays and softer altered have been separated and removed from the natural river sand deposits. This has made difficult the process of extraction and required further tasks to find better quality natural river sands (13, 14).

By contrast, crushed fine aggregates typically consist of a graded material, and contain angular particles with a rough surface texture. Crushed fine aggregate contains, or perhaps even concentrates, weak minerals or particles exposed at the quarry faces. Unless the quarry rock is highly friable or is mono-mineral, manufactured sands comprise broken rock fragments and combined grains rather than a single mineral type. The particle size distribution curve (PSD), for manufactured sand is high in proportions of fines, as opposed to what is normal for natural sand. The best result is expected with a blend of natural and manufactured sand proportions depending on the properties of the specific production process (15, 16).

The difference in surface texture and shape properties indicates that natural and crushed aggregates are two different types of material and must be treated accordingly, that is different requirements apply to the two types. For instance, regarding particle size distribution, knowledge and experience for natural aggregates cannot be used without suitable adjustments. Thus, various demonstrations have to be done to modify and develop standards and manuals as per the nature of the materials (17).

2. Materials and Methods

To achieve the objectives of the research the following three methodologies will be employed. Firstly, this research is made to understand the previous efforts, which include the review of textbooks, periodicals and academic journals, seminars, conferences, and research papers. Secondly, the main research preparation of concrete (C-20, C-30, and C-40) using manufactured sand with mixed designs proportion that has different percent amounts of silt content i.e. 0%, 5%, 10%, and 15%. The tests were conducted on the prepared concrete samples with these sand samples with water cement ratio and similar materials for these mixed proportion concrete. Thirdly, the results and discussion were presented in graphical form, and interpretations, as well as conclusions, were also drawn.

3. Results and Discussions

3.1 Fresh Concrete Properties

The result of the sieve analysis has shown the manufactured sand has oversized that is retained in 9.5 and 12.5 sieve sizes though it is not in pronounced amount. This can be because the machine might not be necessarily equipped to produce a particular manufactured sand. The manufactured sand has a higher fineness modulus and the grading requires blending by ASTM C33 specifications. The material finer than the 75-µm (No.200) sieve consists of the dust of fracture, essentially free of clay or shale, these were under the permitted limits specified in ASTM C33. The results of all sieve analyses for all aggregate samples used in the concrete mix.

Further, workability encompasses the property of concrete that determines its capacity to be placed and consolidated properly and to be finished without harmful segregation and voids created. The results of slump tests were zero in all the first trail mix. Then for the final trail mix adjustments and improvements were made for the first trial mix, and the water-cement ratio became higher to 0.58, 0.54 and 0.45 can be shown in Table 1.
Table 1. Fresh concrete test results of the mixes

No	Mix Code	Silt Content (%)	W/C	Slump Observed (mm)	Strength Concrete
1	NSC 1	0	0.58	47	Normal
2	NSC 2	5	0.58	34	Normal
3	NSC 3	10	0.58	36	Normal
4	NSC 4	15	0.58	23	Normal
5	ISC1	0	0.54	41	Intermediate
6	ISC2	5	0.54	42	Intermediate
7	ISC3	10	0.54	37	Intermediate
8	ISC4	15	0.54	35	Intermediate
9	HSC1	0	0.45	42	High
10	HSC2	5	0.45	38	High
11	HSC3	10	0.45	34	High
12	HSC4	15	0.45	29	High

As can be seen from the test result of research better workability can be achieved with a high water-cement ratio in concrete compared with that of the trail mix. And also as the silt content percent decreases the workability becomes better. However, the higher percentage also gives a better slump achieved in the final mix as shown in Figure 1.

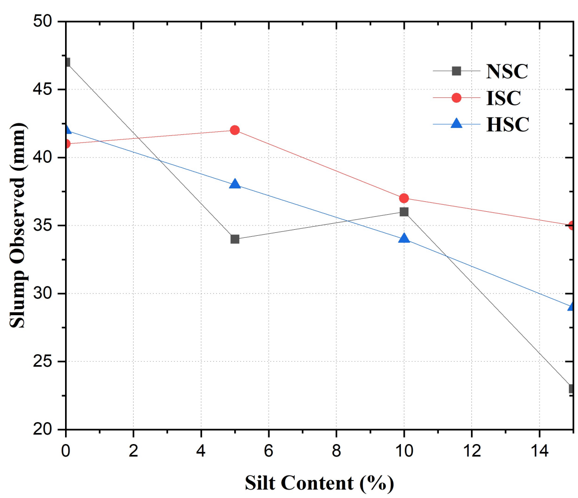

Figure 1. Correlation between slump and silt fine content

Other findings of the research were finishing challenges that face the concrete having manufactured sand. This can be shown at the end of specimens' trail mixes resulting in voids at the surfaces. Better finishing ability was shown in the final mix when the water-cement gets slightly increased and improves created voids.

The effect of using crushed sand with this workability and finish ability might be directly related to the physical nature and fineness content present. Irregular particle shape, rough particle shape, and more fine content on the surface of the aggregate result in difficulty in having a better slump and finishing concrete at a lower water-cement ratio with no aid of chemical solution.

3.2 Hardened Concrete Properties

The manufactured sand has oversize that is retained in 9.5 and 12.5 sieve sizes, according to the results of the sieve analysis, though it is not in a significant amount. This can be the case because the machine isn't necessarily set up to make a specific produced sand. The graded sand needs to be blended by ASTM C33 specifications because the manufactured sand has a greater fineness modulus. The dust of fracture, which is essentially free of clay or shale and was under the allowed limitations stated in ASTM C33, is the material that is finer than the 75-m (No. 200) sieve. The outcomes of each sieve examination for every sample of aggregate utilized in the concrete mix.

Further, the reasonable workability and strength at different silt content (less than 0.063m sieve) percentages were the main objectives of the research work. The compressive strength test carried out on concrete specimens indicates if the concrete structure is carrying loads that act against the structure. It is the most common test carried out on hardened concrete due to some reasons, such as a) standard specifications and structural design codes stipulated mainly based on the compressive strength of concrete; b) as the important property of concrete mostly and directly related to compressive strength concerning serviceability of the material, and c) this test is relatively inexpensive and easy to carry out compared to other test performing at the hardened state of concrete.

These tests of concrete specimens were determined by testing concrete cubes of size 150mm molds. Firstly, all specimens were weighed and measured to determine the area of the cube and the density of the concrete. Then the compressive strength of the concrete specimens with different silt content was determined at 7, 14, and 28 days of age. At each age, a minimum of three specimens with the same amount of silt content were tested to ensure the accuracy of test results. The production of concrete using manufactured sand with different silt percentages and its effect on the compressive strength as if attained as per the requirement was examined. To do so the mix design needed to be made with the same material, proportion, and water-cement ratio but variable silt content percentages were used for these three grade classes of concrete.

The relation between the silt content of manufactured sand and the compressive strength of the three different concrete mixes, NSC, ISC, and HSC are shown in Figure 2, Figure 3, and Figure 4, respectively. Thus the figures confirm that the increase in the compressive strength is achieved when the manufactured sand contains a silt content of 10% and in cases where the target mean strength has shown it is also tolerable the 15% silt content.

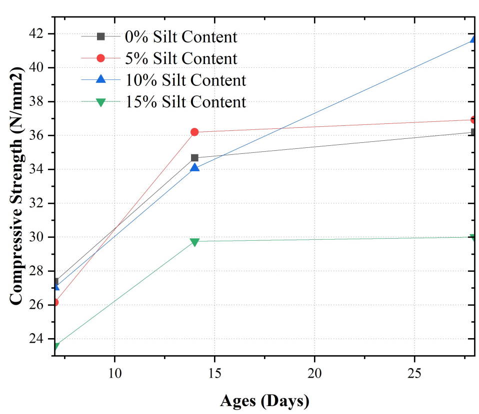

Figure 2. Comparison of compressive strength at various silt content for NSC

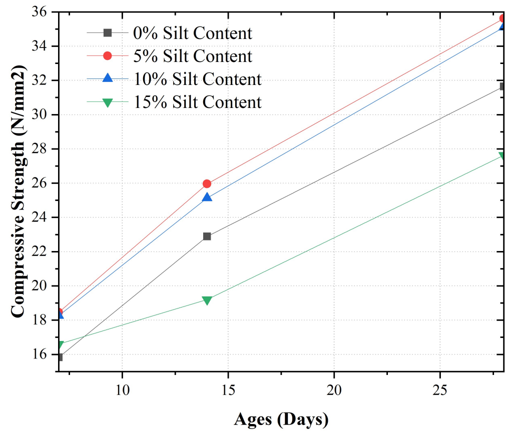

Figure 3. Comparison of compressive strength at various silt content for ISC

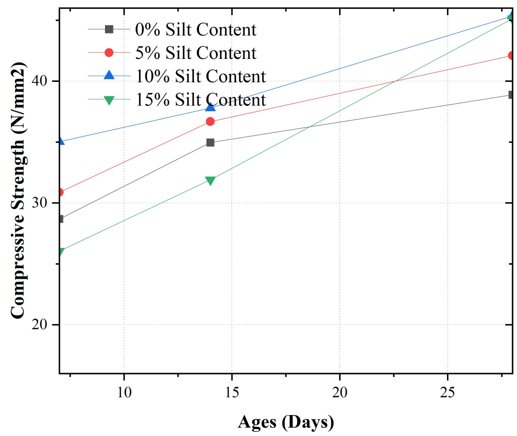

Figure 4. Comparison of compressive strength at various silt content for HSC

The summary of the mean weight and mean compressive strength of concrete made for NSC, ISC, and HSC and tested at the age of 7th, 14th, and 28th days of age are shown in **Error! Reference source not found.**.

Table 2. Summary of mean weight and mean compressive strength of concrete

No	Mix Code	Silt Content (%)	Mean Weight	7 Day Strength	14 Day Strength	28 Day Strength	Strength Concrete
1	NSC 1	0	8236.66	27.38	34.68	34.65	Normal
2	NSC 2	5	8108.33	26.15	36.2	36.93	Normal
3	NSC 3	10	8292.77	27.04	34.07	41.65	Normal
4	NSC 4	15	8208.88	23.59	29.76	30.00	Normal
5	ISC1	0	8183.33	15.83	22.89	31.65	Intermediate
6	ISC2	5	8191.11	18.46	25.96	35.62	Intermediate
7	ISC3	10	8313.33	18.26	25.13	35.11	Intermediate
8	ISC4	15	8156.11	16.60	19.21	27.63	Intermediate
9	HSC1	0	8281.67	28.68	34.96	38.88	High
10	HSC2	5	8292.78	30.87	36.68	42.1	High
11	HSC3	10	8363.33	35.03	37.8	45.35	High
12	HSC4	15	8394.44	26.05	31.9	45.13	High

4. Conclusions

This study investigates redefining the silt content of sand in concrete production. The concrete was produced using manufactured sand having various silt content percentage and their effect on different grade class concrete was examined. After the research work is done and based on the experimental investigation the following conclusions are summarized below;

1. The fresh properties of concrete can be said in all class grade concrete the slump measured decreases as the silt content percentage increases for the same water-cement ratio in each mix design prepared. In all, it can be said that the first trail showed the finishing difficulty and as the percentage of silt content increased the resulting concrete became more difficult to finish. The workability of the concrete made using manufactured sand can be proved by increasing the water-cement ratio without the aid of a chemical solution. As the water-cement ratio increases suitable workability was attained with no pronounced effect on the strength of the concrete.

2. The hardened properties of the mix have shown that the concrete mix for NSC and HSC with 15% silt content proportion achieved a higher compressive strength almost at all tested ages of concrete. However concrete mix for ISC has shown that reasonable strength becomes when the manufacturers have 10% silt content. For the concrete mix of HSC, a compressive strength of 45MPa was produced using manufactured sand having a 15% silt content, and as compared with the target mean compressive strength it can be taken as a considerable result. As a general concrete mix, the silt content limit can be specified as 10-15% can be tolerable.

3. The manufacturers can replace natural sand and can give valuable results for high-strength concrete mix. This is due to the manufactured has a high amount of fineness and irregular particle shape which enhances the concrete compressive strength by filling the voids and making better interlocking of the materials. Locally the process of manufactured sand production has some problems with the installed crushing plant. As we can understand from the sieve analysis result the materials were exhibited as oversize which is out of the specification to define fine aggregate. As compared with the practices throughout the globe, the installed

process here has left with some tasks to fulfill and enhance the quality of manufactured sand. Concerning the environment and resource optimization the use of manufactured sand with high fineness has a vital role in helping to prevent unnecessary damages and in using a comprehensive material usage reduces wastage.

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References

1. Magnani C. A review on need of manufactured sand in concrete as a replacement of river sand. Indian journal of research, paripex 2250-1991. 2014;3:72-4.
2. Padmalal D, Maya k. Sand: The Fine Aggregate. 2014. p. 147-53.
3. Alam M, Habib M, Seikh MR, Hasan A. A Study on the Quality Control of Concrete Production in Dhaka City. IOSR Journal of Mechanical and Civil Engineering. 2016;13:89-98.
4. Bahij S, Omary S, Feugeas F, Amanullah F. Fresh and hardened properties of concrete containing different forms of plastic waste -A review. Waste Management. 2020;113:157-75.
5. Ahmad J, Martínez García R, Vatin N, El-Shorbagy M. Waste Foundry Sand in Concrete Production Instead of Natural River Sand: A Review. Materials. 2022;7.
6. Lam N. A Study on Using Crushed Sand to Replace Natural Sand in High-Strength Self-compacting Concrete Towards Sustainable Development in Construction. IOP Conference Series: Earth and Environmental Science. 2020;505.
7. Jadhav P. Effect of replacement of natural sand by manufactured sand on the properties of cement mortar. International Journal of Civil and Structural Engineering. 2013;3:621-8.
8. Nadimalla A, Masjuki SA, Masjuki B, Khan S. The Effect of Replacement of Natural Sand by Manufactured Sand on the Properties of the Concrete. 2019.
9. S C B, Nikeath D, Pragadesh M. Experimental study on concrete by using manufactured sand – A general review. International Journal of Engineering and Advanced Technology. 2019;8:91-3.
10. Shanmugavadivu PM, Ramesh M, Sindhu M, Feyissa A, Gudeta Y. The Effect of Manufactured Sand in Concrete. International Journal of Advanced Science and Technology. 2020;29:4809-20.
11. Hmar L, Ramhmachhuani R, thlengliani R. Evaluation of Sand Quality and its Effect on Mortar and Cement Concrete. Science & Technology Journal. 2020;8:62-8.
12. Mogre R, Parbat D, Bajad S. Feasibility Of Artificial Sand In Concrete. International Journal of Engineering Research & Technology. 2013;2(7):1607-10.
13. Belay SD. The use of manufactured sand in concrete production: test results and cost comparison. Addis Ababa: Addis Ababa University; 2006.
14. Chandar S, Loganathan S. Demand Analysis on Natural River Sand Used in the Construction Project. 2022. p. 51-60.
15. Arulmoly B, Konthesingha C, Nanayakkara A, Premasiri HM. Optimizing Blending of Manufactured Sand with Offshore Sand Based on Physical and Virtue Characteristics. 2020;6:11-31.
16. Kolawole Olonade, Ibrahim Ajibola, Okeke C. Performance Evaluation of Concrete Made with Sands from Selected Locations in Osun State, Nigeria. Journal of Construction Materials. 2018;8:160-71.
17. Arasan S, Hasiloglu AS, Akbulut S. Shape properties of natural and crushed aggregate using image analysis. International Journal of Civil and Structural Engineering. 2010;1:221-33.