Quality Assessment of River Sand from Different Sources Used in Construction Purposes in Duhok Governorate at Kurdistan – Iraq

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Abstract: Concrete is the most widely used construction material in the world. Some previous studies claim that substandard and low-quality concrete materials account for the majority of building collapse causes. These have mainly been attributed to the poor quality of concrete ingredients. Data regarding the clay and silt content in the river sand sources, and their impact on concrete's compressive strength that is used in construction in Duhok and its surroundings were missing. Aggregates usually affect freshly mixed proportions and properties. This research aimed to investigate the quality of sand & its impact on the concrete's compressive strength. Natural river sand assessment was carried out, which is used as fine aggregate in concrete production, in this case, in Duhok city and its surroundings. Five sand sources (Kalaka Yasen Axa, Khazir, Gomly, Khabur, and Dijla) were chosen for the study. Each source sample was subjected to sieve analysis, fineness modulus (FM), silt and clay content, specific gravity, and compressive strength of concrete made with these sand types. It was deduced that Duhok and its surroundings' sand from Kalaka Yasen Axa and Khazir is composed of clay and silt content exceeding the allowable Iraqi specifications (IQS) and British Standard (B.S) limits. This has caused a significant drop in concrete strength. It was found that the concrete mixtures suffer from strength reduction as a result of the gradation and impurities of the sand used. Also, the sand samples with fineness modulus values outside the standards range are more likely to cause concrete workability issues.

Keywords: Concrete, Fine Aggregate, River Sand, Sand Quality, Compressive Strength, Construction

1. Introduction

Concrete is the most used construction material worldwide (Neville, 1994). The standard procedure for making concrete is by mixing Portland cement with crushed rock, water, and sand. It is a composite material consisting of a binding medium. Within the medium, there are embedded fragments or particles of aggregate. Aggregates are used as filler materials in binding for the production of concrete and mortar. Aggregates usually form the concrete body, affect the economy, and reduce shrinkage. They typically occupy between 70 and 80 percent of the volume. They also have a significant effect on the concrete properties. Aggregates should always be graded in size, durable, strong, hard, and clean for utmost economical purposes in the paste (Mehta, 2001).

Aggregates are used in two different remarkable sizes to increase the concrete's bulk density. Bigger aggregates are known as coarse aggregate (grit), while the smaller aggregates are referred to as fine aggregate (sand). Fine aggregates that pass through a 4.75 mm sieve are described as 'fine.' These can

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be crushed gravel sand (obtained by crushing gravel), crushed stone sand (brought by grinding stones), or natural sand deposited by rivers (Mehta, 2001). In Duhok governorate, sand from rivers is primarily used as fine aggregates in concrete production due to numerous rivers deposited with sand.

Deficiency use of materials quality is one of the principal causes of building failures. Concrete structures failure leads to buildings collapsing. This has resulted in an accelerated rise of various studies on the construction materials quality (Wardhana & Hadipriono, 2003). These have mainly been attributed to the poor quality of concrete ingredients. It is crucial to control and manage the quality of the aggregate materials in concrete making (Olanitori, 2006). The fine aggregate quality can vary significantly based on their environmental conditions and geographical locations (Oke, 2011). Aggregates diverged from the sea, creeks, rivers, or those obtained from pits are often not well-graded or clean enough to meet the quality requirement of sand. The aggregates require washing and sieving before their use in concrete production for construction activities (Gurcharah, 1983).

The major factors determining the quality of the fine aggregates include clay and silt content, and their gradation. Silt materials refer to fine aggregate particles smaller than 75lm (No. 200) sieve size. They start reacting like swelling and shrinking concrete with non-cohesive properties for which they do not react with fine aggregates, water, and cement. However, they still exist in concrete, causing significant cracks or sometimes unwanted hairlines in the concrete. The sand’s silt content effect on the concrete’s compressive strength must be controlled (Alexander & Mindess, 2005). Moreover, fine aggregate grading significantly influences concrete's physical properties. Suppose the fine aggregates are too coarse; the result is a rough mix prone to segregation and bleeding. Suppose the aggregates are too fine; the result is a large surface area for segregation and increased water demand (Orchard, 1979).

2. Case of study

The quality assurance for the residential investment projects and constructions in Duhok is controlled and managed by the government; meanwhile, the quality control of the materials used for the residential projects that the owner constructs. Residential homes often experience several problems and issues resulting from low-quality materials, most prefer the application of such low-quality materials because they are cheaper compared to others (Hawar, Mudhafer, & Sheimaa, 2020). The fine aggregates currently used in the Duhok governorate are mainly mined from large channels and rivers. Many people supply sand to the markets without checking its quality. Most of these suppliers lack technical information regarding the appropriate aggregate use, resulting in concrete processing failure. Additional details concerning sand sources used in the construction industry in the Duhok can be helpful to prevent such cases. In preventing concrete production from failing, careful construction materials selection, especially building sand, is vital to ensure the set standards in construction are met.

This project aims to conduct a qualitative laboratory assessment of fine aggregates and demonstrate their working construction suitability and quality assurance. Five fine aggregate samples (Kalaka Yasen Axa, Khazir, Gomly, Khabur, and Dijla) were collected from the Duhok governorate. Several physical properties tests (Specific gravity, sieve analysis, and silt and clay content (clay%)) were analyzed according to the American Society for Testing and Materials (ASTM C33-C33M-18, ASTM C136 / C136M - 19, ASTM C128 - 15, 1 ASTM C117 - 17, and ASTM C39 (1990)) (Annual Book of ASTM Standard, 1990, 2015, 2017, and 2018), British Standard (BS, 1992, 1983, and 1995), and Iraqi specifications (IQS, 1984). Also, the impact of sand sources on the concrete’s compressive strength in Duhok city & its surroundings.

3. Materials

Five river sand sources were chosen regarding the field assessment results by interviews with contractors, suppliers, and consultants in aggregates within Duhok city to show data on the locations of sources of fine aggregates in the area of study. The selected sand and locations as sources for use in concrete production in Duhok Governorate are as follows:

1. Kalaka Yasen Axa sand is a local name of sand taken from Great Zab River, in Kalaka Yasen Axa village in Bardarash district -Duhok Governorate, the Great Zab or Upper Zab is an approximately 400-kilometer (250 mi) long river flowing through Turkey and Iraq.
2. Khazir sand is a local name of sand taken from Khazir River in Qasrok Sub-district -Duhok Governorate, Khazir River is a tributary of the Great Zab River.
3. Gomly sand is a local name of sand taken from Gomly River near Atrosh Bridge in Sheikhan District -Duhok Governorate, this river is a seasonal river.
4. Khabur sand is a local name of sand taken from Little Khabur River in Zakho District at Two-kere village-Duhok Governorate. The Khabur or Little Khabur is river that rises in Turkey and flows through Iraq to join the Tigris at the tripoint of Turkey, Iraq and Syria.
5. Dijla Sand is a local name of sand taken from Tigris River in Derabon subdistrict-Duhok Governorate, which is the triangle border between Iraq, Turkey, and Syria.

Data were acquired from collected sand samples. The sand samples' color varies based on their environmental conditions and geographical locations as shown in the figure 1.

Figure 1: Sand samples

The sampling procedure was carried out according to The ASTM C702 where it provided info on the sampling procedure adopted to reduce the field sample and obtain the test portion required for each test conducted and samples collected. Clean samples were properly bagged in the waterproof leather sack, labeled accordingly, and then transferred to the technical college of engineering laboratory at Duhok Polytechnic University. Each source sand was then subjected to a series of laboratory tests per ASTM standards. ASTM C136, ASTM C128, and ASTM C117 were used for Particle size distribution analysis, specific gravity, and number of materials finer than 75-μm (No. 200) sieve by washing, respectively.

Thirty cubes were cast in all to assess the compressive strength of concrete produced during the experiment, meaning six cubes for each sand source location were cast, three each out of the six cubes were used to determine the 7 and 28-day compressive strength of the cubes. The 1:1.5:3:0.5 concrete mix ratio (cement: fine aggregate: coarse aggregate: water), as commonly applied in most low-rise design buildings, was prepared for an anticipated 20 MPa compressive strength on the 28th day according to BS. This involved using common Portland cement and a 16 mm maximum aggregates size, with slump testing performed on fresh concrete. Finally, 150mm concrete cubes were prepared, compacted, de-molded a day after casting, and then cured in a water tank for 28 days. Compressive strength tests for the concrete cubes were conducted as per ASTM specification. Some of the laboratory work photos was shown in Figure 2.

Figure 2: laboratory work procedures photos

4. Results and Discussion

A summary of the experimental results of the physical properties and compressive strength test of the river sand sources is shown in this section and illustrated in the Figures. All experimental results for sand samples are subjected to a series of laboratory tests were compared with the requirements of the selected codes (ASTM, BS, and IQS).

4.1. Sieve Analysis Results

The sieve analysis results of sand samples compared with ASTM standard limitation are shown in Figure 3, samples Kalaka Yasen Axa, Khazir, Khabur, and Dijla failed to meet the sieve sizes no.4 & 8. However, these samples satisfied the limitation on other sieves. For this fact, more particle sizes are needed to retain on sieves no.4 & 8. In these samples, almost all sieve sizes (except no.4 & 8) were satisfied. Sample Gomly failed to meet the sieve sizes no.4, 16, 30, and 50 per ASTM. However, Sample Gomly satisfied the limitation on other sieves.

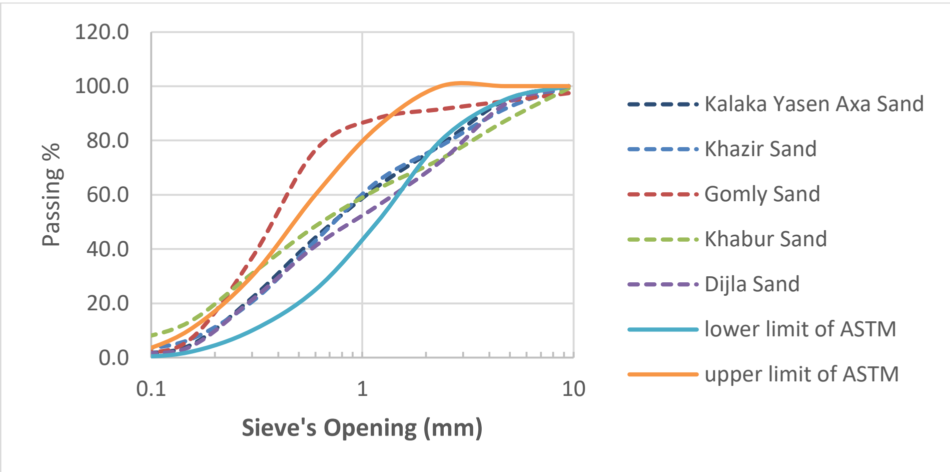


Figure 3: Sieve analysis results of sand samples with ASTM

Figure 4 shows the results of the sieve analysis of sand samples compared with BS standard limitation, all Samples appear to be within Grading Zone C and M for the British Standard (BS), where there is no deviation in value. Limits for grading C or M in accordance with BS 812 (BS, 1995) is recommended for use in heavy-duty concrete floor finishes.

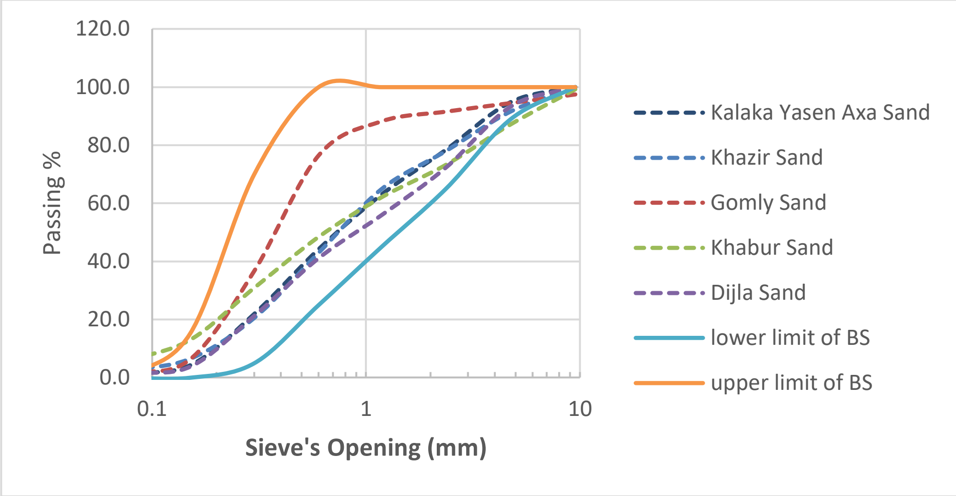


Figure 4: Sieve analysis results of sand samples with BS

The sieve analysis results of sand samples compared with IQS standard limitation are shown in Figures 5 and 6, Samples Kalaka Yasen Axa, Khazir, Khabur, and Dijla can be rated in Grading Zone II, with a slight deviation of 2.76% in value for sieve No.4, 1.74% for sieve No.8, 0.89% for sieve No.50, and 2.93% for sieve No.200 for Khabur sample; and a slight deviation of 2.71% in value for sieve No.8 for Dijla sample. Variations of below 5% are acceptable according to IQS recommendation. Meanwhile, sample Gomly can be rated in Grading Zone III without deviation in sieves.

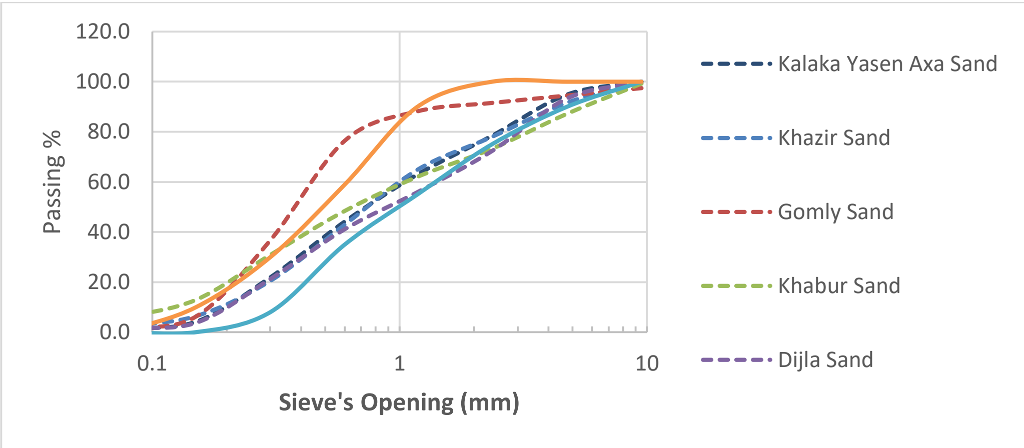


Figure 5: Sieve analysis results of sand samples with IQS-Grading Zone II

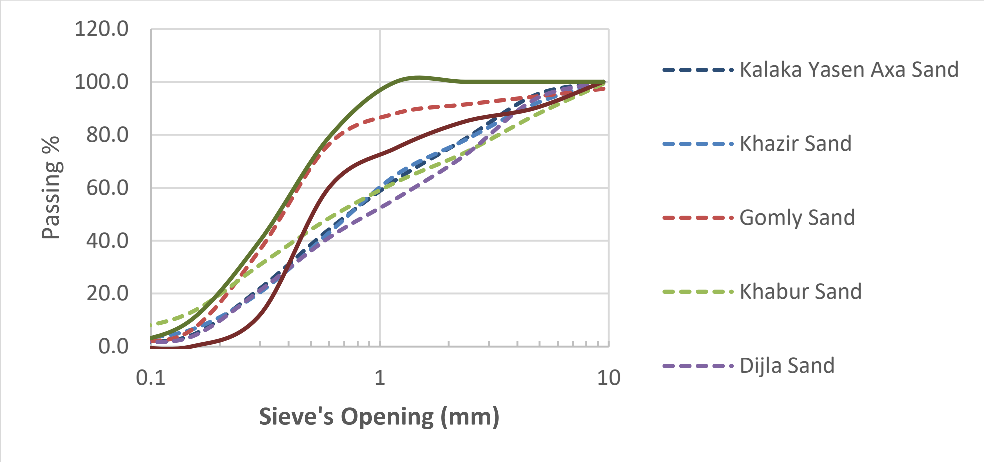


Figure 6: Sieve analysis results of sand samples with IQS-Grading Zone III

4.2. Fineness Modulus (FM)

The fine aggregate gradation was evaluated per the ASTM standard. For an excellent fine aggregate, the Fineness Modulus (FM) is supposed to be between 2.3 and 3.1, which is the ASTM Range for fine aggregates. The result showed that samples Kalaka Yasen Axa, Khazir, and Khabur had fineness modulus within the ASTM standard range within the coarse sand limit. Other samples had FM values outside this range on either extreme side, with sample Gomly having the lowest FM value of 2.09 while sample Dijla had the highest FM value of 3.12, as shown in Figure 7. Generally, samples with fineness modulus values outside the standard range are more likely to cause workability issues. These samples can be supplemented with mineral admixture in their deficiency areas for workability; perhaps this is necessary. Finer sand is not recommended in concrete since it is uneconomical.

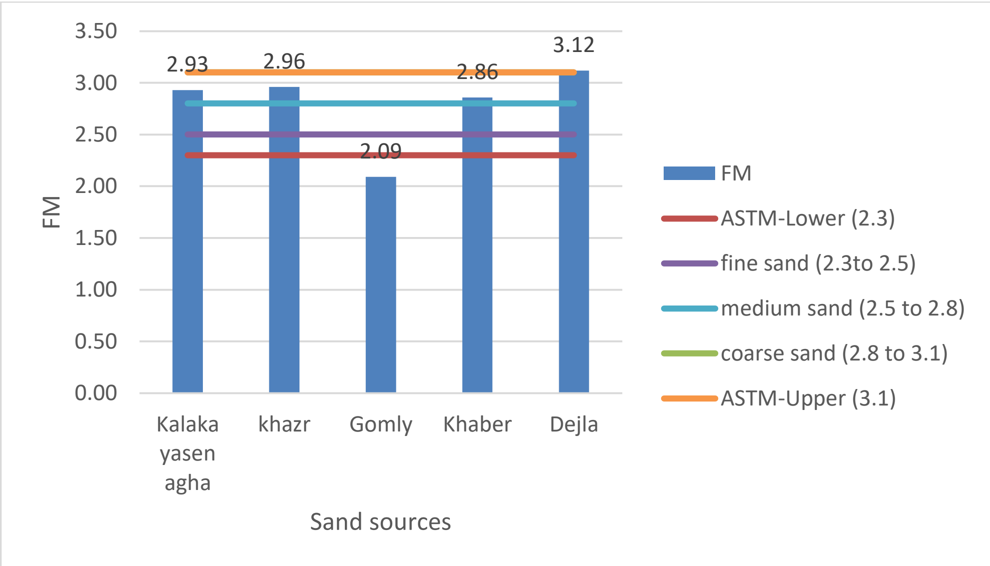


Figure 7: Fineness Modulus of Sand samples

4.3. Specific Gravity

Sand samples were tested for specific gravity according to ASTM C33 for aggregate materials under 10mm in diameter by the pycnometer glass vessel. The specific gravity of sand samples is shown in figure 8, it shows that the highest value was for Kalaka Yasin Axa with 2.73, while the lowest value for Gomly was 2.59.

The results indicated that the standard and average specific gravity was 2.65. The anticipated specific gravity ranges for sand applied in producing concrete was (2.40 – 3.00) for normal sand per ASTM C33, which implies that the sand applied in the study represented the common sand utilized in making concrete. This shows that the five sand samples were in the average/standard range used in sand building.

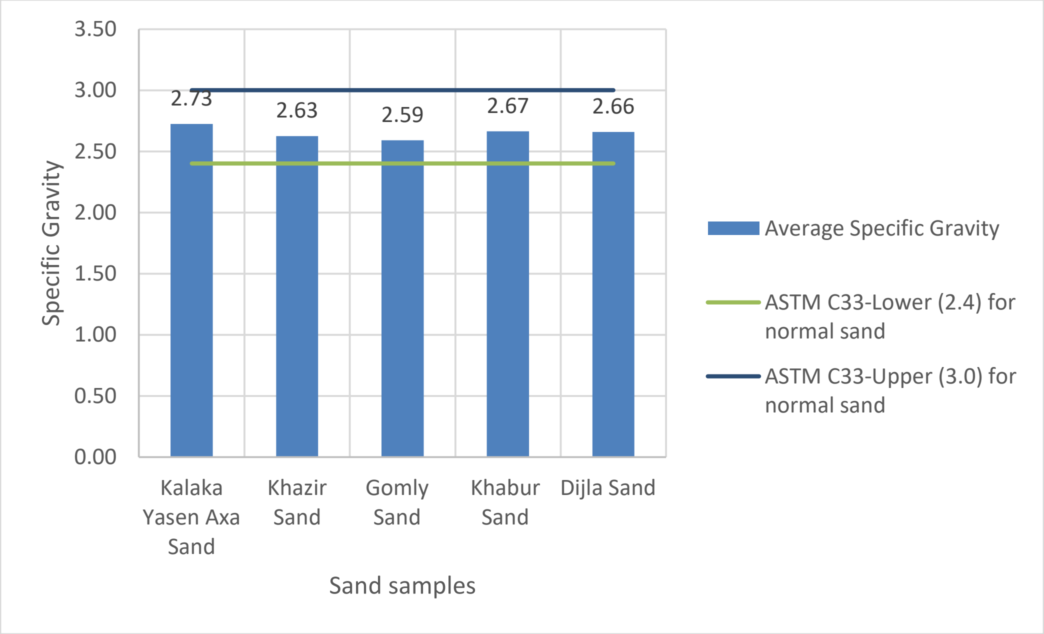


Figure 8: Specific Gravity of Sand samples

4.4. Deleterious Materials (Clay %), Silt and Clay Content in Sand

Figure 9 shows the results of silt and clay content on the sand sample sources tested, the maximum silt and clay content was 9.2% for sand sample Kalaka Yasen Axa compared with the 2.8% minimum silt & clay content for sand sample Khabur. The British Standard recommends that the maximum clay and silt content of 4% for fine aggregate be used in concrete production. Out of five samples, only one attained the limit was Khabur sample, which represents only 20%. This means an overwhelming 80% failed to meet the British Standard. Comparatively, the allowable silt and clay content in sand samples used in producing concrete per the ASTM is 10% in weight.

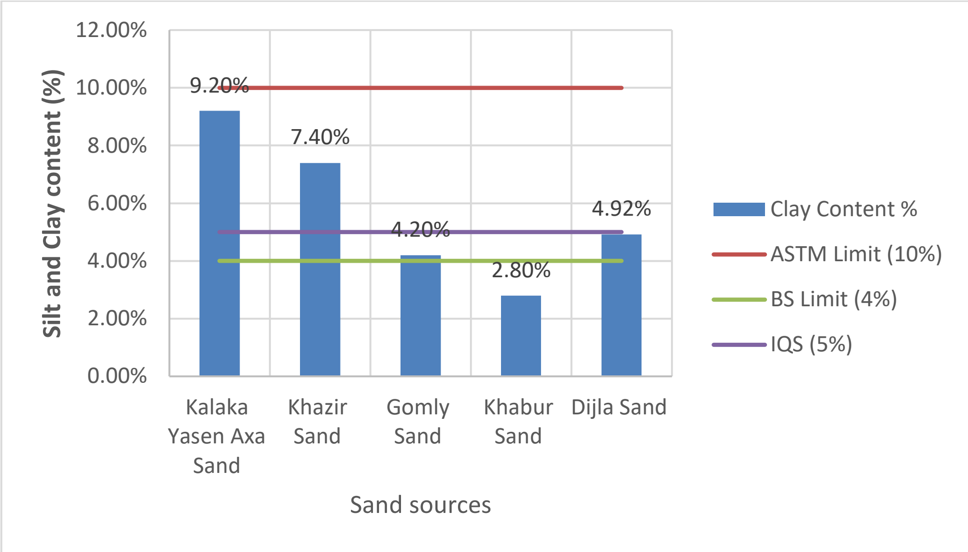


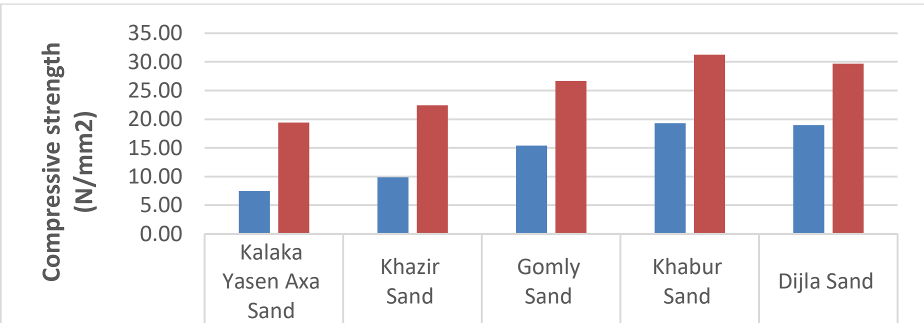
Figure 9: Silt and clay content in Sand samples

All sand samples met the limit, which implies a nonfailure of the sand samples tested according to ASTM standard. Two sand samples had silt content above 5% which are Kalaka Yasen Axa and Khazir samples, which is the maximum allowable value. Out of the five samples, three meet this limit Iraqi.

From Figure 9, the maximum clay & silt content recorded from the five samples was significantly 9.2%, implying that 92 kg has a composition of clay & silt impurities for a ton of sand. Therefore, money value is not achieved when this sand is purchased to construct as the average sand quantity standard comprises clay and silt impurities.

4.5. Compressive Strength Results

A concrete compressive strength test was done per the ASTM and British Standard. In each sample, six cubes were cast & cured at room temperature underwater. Followed 3 concrete cubes created in every sand sample tested on days 7 and 28. The average value was afterward obtained from the three tested cubes. The final results were as shown in Figure 10. The anticipated compressive strength at days 7 and 28 is also as indicated. It is crucial to state that a uniform mix design utilized in the majority of low-rise designed buildings was applied.



	Kalaka Yasen Axa Sand	Khazir Sand	Gomly Sand	Khabur Sand	Dijla Sand
7 days Mpa	7.45	9.86	15.37	19.29	18.98
28 days Mpa	19.42	22.43	26.69	31.26	29.70

Figure 10: Compressive strength of concrete cubes at age of 7, and 28 days of sand samples

The compressive strength of concrete cubes at age of 7, and 28 days of sand samples are shown in Figure 10, sand sample Kalaka Yasen Axa, failed to attain the minimum expected strength on days 7 and 28, which is only one of the five samples. Since all five samples were placed in a similar cast and cure conditions, the failure can significantly be associated with clay and silt content present in the sand, and, rarely to, particle shapes, sizes, and texture. It was also noted that the failed sample on the 7th day also failed on the 28th day. It was concluded that sand sample Kalaka Yasen Axa had the maximum silt and clay content was 9.2% is more than 4% for BS, 5% for IQS, and closely to 10% for ASTM which are the minimum impurities' levels standards. Finally, any sample with 10% or more clay & silt content and organic impurities is most likely to fail.

5. Conclusion

Overall, the following conclusions are drawn from the assessment of the quality of river sand from different sources in Duhok Governorate for construction purposes are:

1. Samples Kalaka Yasen Axa, Khazir, Khabur, and Dijla failed to meet the sieve sizes no.4 & 8, Sample Gomly sand failed to meet the sieve sizes no.4, 16, 30, and 50 per ASTM. However, all samples satisfied the limitation on other sieves. All Samples appear to be within Grading Zone C and M for the British Standard (BS), where there is no deviation in value. Samples Kalaka Yasen Axa, Khazir, Khabur, and Dijla can be rated in Grading Zone II, with a slight deviation in sieves No.4, No.8, No.50, and No.200 for Khabur Sand; and a slight deviation in sieve No.8 for Dijla Sand. That variations are acceptable as per IQS standard.
2. Fineness modulus (FM) of Sample Gomly sand is lower than other Samples Kalaka Yasen Axa sand, Khazir sand, Khabur, and Dijla by percent (0.287, 0.29, 0.268, 0.33), respectively.
3. It is found that most of the river sand sources which are used in this research contained silt and clay contents that exceeded the allowable limits for unwashed sand. Deleterious materials (silt and clay content) of sand samples from Khabur, Gomly and Dijla rivers sources are (2.8%, 4.2%, and 4.92%) respectively, and they are within the Iraqi specification that is 5%. While the sand samples Khazir, and Kalaka Yasen Axa rivers sources are higher than the Iraqi specification as compared by percent (2.4, 4.2) respectively. Only sand sample from Khabur river source within the BS recommends that the maximum clay and silt content is 4%. Comparatively, the allowable silt and clay content in sand per the ASTM is 10%, all samples within the ASTM.
4. The specific gravity of Kalaka Yasen Axa Sand sample is slightly higher than other samples Khazir Sand, Gomly Sand, Khabur Sand, Dijla Sand by percent (0.04, 0.05, 0.02, 0.02) respectively.
5. The compressive strength of Khabur Sand is (19.29, 31.26) MPa for (7, 28) days, and it is slightly higher than Dijla Sand and Gomly Sand by percent (0.02, 0.05) MPa and (0.21, 0.15) MPa for (7, 28) days, respectively, and much higher than Khazir sand and Kalaka Yasen Axa sand by percent (0.49, 0.28) MPa and (0.61, 0.38) MPa for (7, 28) day, respectively.
6. It observed that the compressive strength of concrete is decreased by increasing the presence of silt and clay content and organic impurities in the sand, the level of content it when exceeding the allowable standards which are significantly contributed may lead to the collapse of structures if not considered in the concrete mix design. The samples from Kalaka Yasen Axa sand can be solved the clay content issue by washing sand with water.
7. Sand impurities negatively impact bond and comprehensive strengths between steel and concrete reinforcement; such may cause building failures.

8. Constituent materials' quality in concrete preparation plays a significant role in developing the resultant concrete's strength and hardness properties. These have mainly been attributed to the poor quality of concrete ingredients. It is crucial to control and manage the quality of the aggregate materials in concrete making.
9. Deficiency use of materials quality is one of the principal causes of failed compressive strength of concrete.

It is recommended that the sand types of Kalaka Yasen Axa and Khazir should not be used for construction unless the sands are washed and sieved. Fine aggregate should be properly washed before using since most of them are contains silt, clay, mud and other impurities which hinder the process of bonding.

References

Alexander, M., & Mindess, S. (2005). *Aggregates in concrete*. Oxon: Taylor and Francis.

ASTM C33 / C33M-18, Standard specification for concrete aggregates, ASTM international, West Conshohocken, PA, 2018,

ASTM C39 (1990). Standard method of test for compressive strength of concrete specimens. ASTM International,West Conshohocken,

ASTM C117-17, Standard test method for materials finer than 75-µm (No. 200) sieve in mineral aggregates by washing, ASTM International, West Conshohocken, PA, 2017,

ASTM C128-15, Standard test method for relative density (specific gravity) and absorption of fine aggregate, ASTM International, West Conshohocken, PA, 2015,

ASTM C136 / C136M-19, Standard test method for sieve analysis of fine and coarse aggregates, ASTM International, West Conshohocken, PA, 2019,

ASTM C702 / C702M-18, Standard practice for reducing samples of aggregate to testing size, ASTM International, West Conshohocken, PA, 2018,

BS 812 (1995). Methods for sampling and testing of mineral aggregates, sands and fillers. Part 103. British Standard Institution, London.

BS 882 (1992). Specification for aggregates from natural sources for concrete. British Standards Institution, London.

BS 1881-120 (1983). Testing concrete method for determination of compressive strength of concrete cores. British Standards Institute, London.

Gurcharah, S. (1983). *Highway engineering*. 1st Edition, Blackwell Publishing Company. USA.

Hawar H. J., Mudhafer H. S., & Sheimaa I. M. (2020). Quality assessment of reinforcing steel used in residential building in Duhok City at Kurdistan - Iraq, 2020 International Conference on Advanced Science and Engineering (ICOASE), 2020, pp. 1-5, doi: 10.1109/ICOASE51841.2020.9436571.

Iraqi Specification No.5/1984. Aggregate from natural sources for concrete and construction. Central Organization for Standardization and Quality Control, Baghdad, No.5/1984, 2001.

Mehta, P. K., & Monteiro, P. J. M. (2001). Concrete microstructure, properties and materials. (2nd ed.), Mc Graw-Hill Professional, New York.

Neville A.M., & Brooks J.J. (1994). *Concrete technology*. England: Longman Scientific and Technical

Oke, A. (2011). An Examination of the causes and effects of building collapse in Nigeria. *Journal of Design and Built Environment*, 9, 37-47.

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.

Orchard, D.F. (1979). *Concrete technology*. *Properties of material*. 4th Ed. London: Volume Applied Science Publishers Ltd.

Wardhana, K., & Hadipriono F.C. (2003). Study of recent building failures in the United States. *Journal of Performance of Constructed Facilities* 17(3), 151-158.