



A Comparative Assessment of Uncrushed-River Concrete Mix of Hari-River, and Kamar-Kalaq: the Two Widely Used Concrete Mix in Herat, Afghanistan

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ABSTRACT

Concrete, as a cornerstone of modern construction, heavily relies on the quality of its constituent materials, particularly aggregates. This study delves into a comparative analysis of aggregates sourced from two widely utilized riverbed regions, namely Hari-River and Kamar-Kalaq, situated within Herat province, Afghanistan. Given that over 90% of concrete in Herat province is sourced from these two riverbeds, the findings of this study carry immense significance. The research meticulously examines key parameters, including clay content, gradation, aggregate shape, and compressive strength, to determine the optimal choice for concrete production. Methodologically, samples were acquired following ASTM standards, and rigorous testing procedures were conducted, encompassing clay particle analysis, sieve analysis, and strength testing. The results reveal significant disparities between the two regions, with Hari-River demonstrating superior characteristics across various metrics. Particularly noteworthy is Hari-River's lower clay content, superior gradation, and higher compressive strength compared to Kamar-Kalaq.

INTRODUCTION

Concrete, as one of the most utilized human-made materials globally, holds a significant position in construction (Li, Yoon, Zhang, and others, 2022). The global consumption of concrete exceeds that of steel, wood, plastics, and aluminum combined by a factor of two (Wang, Gao, Ji, Stewart, & Arson, 2020). Concrete's most distinctive attribute is its exceptional compressive strength, a quality that varies depending on various factors. Typical concrete consists of readily available and locally sourced materials, including coarse aggregates (such as rock), fine aggregates (like sand), binding material (such as cement), and water. These components are generally cost-effective and abundant within the construction area. (Nguyen, Vu, Vo, & Thai, 2021). Aggregates occupy a significant portion, ranging from 60% to 90%, of the total volume of concrete (Shakhmenko, & Birsh, 1998). The proper selection of aggregate type and particle size distribution significantly influences key properties of concrete, including workability, mechanical strength, permeability, durability, and overall cost. Therefore, designing the aggregate mix is a crucial aspect of optimizing concrete mix design (Aginam, Umenwaliri, & Nwakire, 2013). The ASTM standard establishes both upper and lower limits on concrete gradation to ensure that the mix achieves its maximum strength concerning gradation. However, concrete aggregates may occasionally contain impurities such as clay particles, which can adversely affect concrete properties (Désiré, & Léopold, 2013). The strength of concrete is inversely correlated with the quantity of clay particles present in the aggregates (Désiré, & Léopold, 2013). Clay particles retain significant amounts of water, leading to evaporation during volume changes in concrete. This evaporation can result in cracking and reduced concrete strength (Li, Zhou, Ma, & Hou, 2022). Additionally, the shape of the aggregate significantly impacts concrete strength. Crushed aggregates, typically angular in shape, foster stronger bonds and yield higher concrete strength. Conversely, uncrushed aggregates diminish the compressive strength of concrete (Li, Zhou, Ma, & Hou, 2022). Despite ASTM regulations prohibiting the use of uncrushed aggregate in concrete, it remains the primary type of aggregate in some developing countries. In Afghanistan, particularly in Herat province, uncrushed aggregate prevails over crushed due to its threefold lower cost. The uncrushed aggregates utilized in Herat originate from riverbeds, constituting a natural blend of both fine and coarse aggregate, alongside varying amounts of clay particles. The Hari-River and Kamar-Kalaq regions in Herat province are renowned for their uncrushed aggregates. However, selecting between the two regions has posed challenges for structural engineers and contractors. For years, the question of which region boasts the optimal soil type for selection has persisted. Discrepancies abound regarding soil composition, strength, and gradation in these regions, with no published research addressing these disparities. This study aims to compare the strength, gradation, percentage of clay, and aggregate shape between the two

regions to determine the most suitable option for concrete production in the province.

Methodology

The total length of the Hari-River and Kamar-Kalaq, where aggregates are primarily sourced, was measured to be 4000m and 352m, respectively. To obtain representative samples, two sample locations were randomly selected along each river using a random number generation method based on Table 1 of ASTM D 3665. The randomly generated numbers selected for Hari-River were 0.355 and 0.05, corresponding to lengths of $(0.355 \times 4000) = 1420\text{m}$ and $(0.05 \times 4000) = 200\text{m}$. For Kamar-Kalaq, the selected numbers were 0.159 and 0.232, corresponding to lengths of $(0.159 \times 352) = 56\text{m}$ and $(0.232 \times 352) = 82\text{m}$. So samples were taken from the 1420m and 200m points along the Hari-River, and two samples were taken from the 56m and 82m points along the Kamar-Kalaq. To facilitate laboratory testing and analysis, the samples were reduced in size using the procedure outlined in ASTM C 702-98.

To determine the percentage of clay particles in the sample, the washing method outlined in ASTM 117-04 was employed. Initially, the sample from the bag was thoroughly dried in an oven, and its weight was measured. Subsequently, the dried sample was placed in a container, and water devoid of any detergent or dispersing agent was added, figure 1. Through vigorous agitation, finer particles than the $75\ \mu\text{m}$ (No.200) sieve were separated from coarser particles, forming a suspension of fine materials. This suspension was poured into a nested sieve setup, with a coarser sieve positioned above it, and the process was repeated until the water ran clear. Following this, the sample was dried again, and its weight



Figure 1. Series of images capturing the washing procedure utilized to determine the percentage of clay content in the sample.

was calculated. The calculated weight was then subtracted from the initial dried weight to determine the weight of the clay particles.

To determine the soil's gradation, the washed sample, devoid of any clay and silt, underwent sieve analysis in accordance with ASTM C 136-06, figure 2. A sturdy frame, complying with ASTM standards, was fitted with sieve cloth covering openings ranging from 63mm to 75 μ m. The sieve cloth was then subjected to shaking for a duration of 15 minutes. Subsequently, the mass retained on each sieve was measured to calculate the percentage passing through. Notably, the limits stipulated by ASTM C 136-06 in table 7.4 for coarse aggregate were not assessed, as the sample, being uncrushed, naturally encompasses all types of



Figure 2. Depicting the equipment utilized in the sieve analysis procedure.

gradation.

To conduct the strength test, new samples were extracted from the bag to accurately represent the characteristic of natural riverbed, including the presence of clay particles. These samples were then used to fill cylindrical molds, figure 3. Following a predetermined ratio of three portions of aggregate to one portion of cement, water was added carefully until a slump of 10 centimeters was achieved, reflecting the standard practice adopted in all construction projects in Herat province, figure 3. For the slump test, a standard mold meeting the specifications outlined in ASTM C 143-10 was utilized, figure 3. Similarly, standard cylinder molds equipped with tamping rods as per ASTM C 31-09 were employed to prepare cylinder blocks for compression testing.



Figure 3. showing slump pouring process with cylinder mold and accompanying materials for concrete casting

Molding requirements were selected in accordance with ASTM C 31-09, and curing was conducted as per the guidelines outlined in ASTM C 31-09. In total, six cylindrical samples were prepared for each site, comprising three samples subjected to a 7-day testing period and three samples subjected to a 28-day testing period, figure 4.



Figure 4 .Representation of a concrete cylinder with caps on both ends, both before and after undergoing compression testing.

Following the sieving process, the samples were arranged adjacent to each other, allowing for a visual inspection and comparison of the aggregate shapes.

Result and discussion

The results indicate that Kamar-Kalaq soil contains 3.7% clay, whereas Hari-River soil contains 2.7% clay. The clay content in Hari-River soil falls within the maximum limit of 3% specified by ASTM C 33-08. However, the clay content in Kamar-Kalaq soil exceeds this limit, rendering it unacceptable according to the specified standard.

The results of sieve analysis reveal that the coarse aggregate from Kamar-Kalaq generally falls within the size number 67 range prescribed by ASTM, as depicted in Figure 7. However, the gradation of the fine aggregate fails to meet the specified limits, as illustrated in Figure 8. It is observed that the coarse aggregate from Kamar-Kalaq tends to cluster around the upper and lower bounds of size number 67, a practice discouraged by ASTM standards, as depicted in Figure 7. This highlights the inadequate gradation of Kamar-Kalaq, suggesting potential voids within concrete mixes and consequently, reduced strength. In contrast, both fine and coarse aggregate gradations from Hari-River comfortably adhere to acceptable ranges, showcasing superior gradation compared to Kamar-Kalaq, as evident in Figures 6 and 5. The fineness modulus for fine aggregate from Hari-River measures 4.911, while for Kamar-Kalaq, it registers 5.641. ASTM C 33 standards stipulate a fineness modulus for fine aggregate not exceeding 3.1 or

falling below 2.3. However, both Hari-River and Kamar-Kalaq surpass the 3.1 threshold, indicating a tendency towards coarser grading.

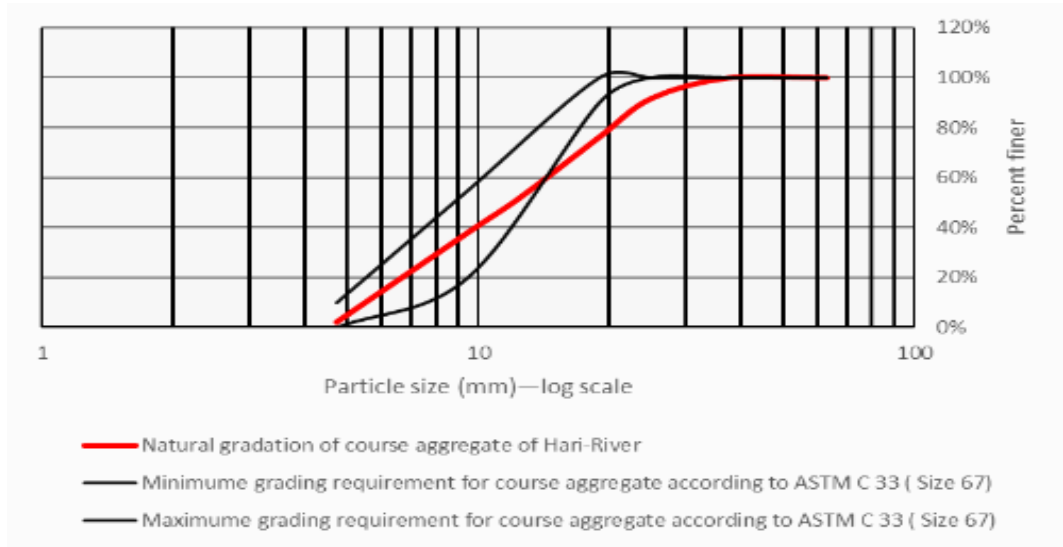


Figure 5. Shows course aggregate gradation of Hari- River compared to ASTM size no. 67, in logarithmic scale

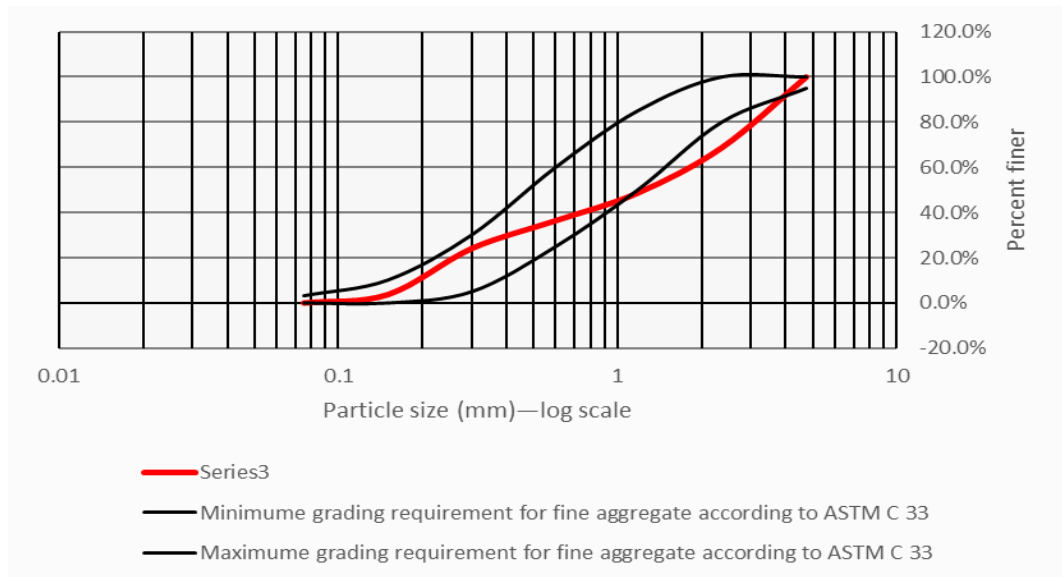


Figure 6. Shows fine aggregate gradation of Hari- River compared to ASTM size no. 67, in logarithmic scale

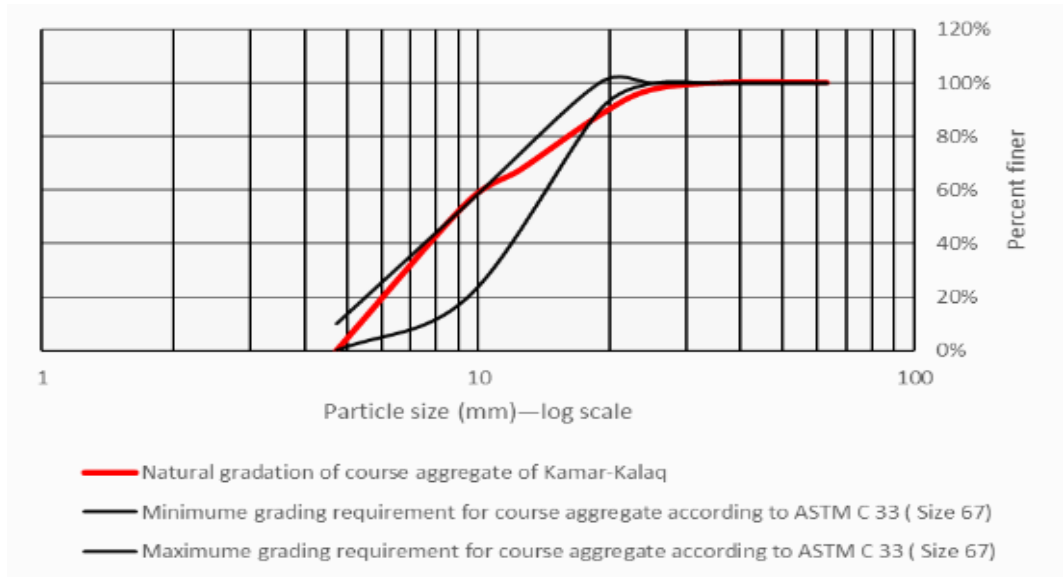


Figure 7. Shows course aggregate gradation of Kamar-Kalaq compared to ASTM size no. 67, in logarithmic scale

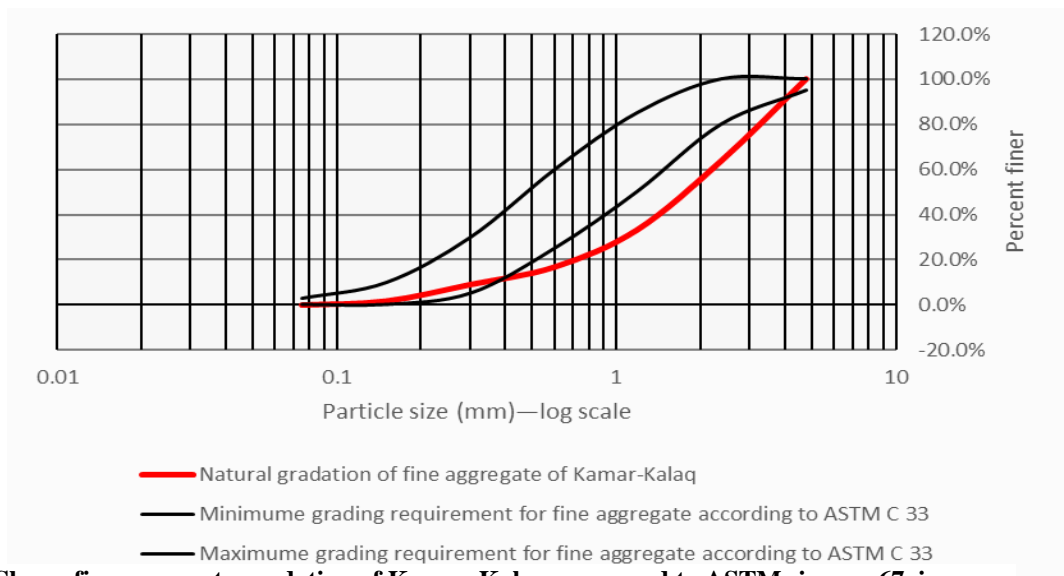


Figure 8. Shows fine aggregate gradation of Kamar-Kalaq compared to ASTM size no. 67, in logarithmic scale

Figures 9 and 10 present a comparative analysis of percent retained on sieves for both fine and coarse aggregates from Kamar-Kalaq and Hari-River. As depicted in Figure 9, the fine aggregate from Hari-River exhibits significantly higher fineness compared to that of Kamar-Kalaq. This observation is further supported by the fineness modulus, indicating the superior ability of Hari-River's fine aggregate to fill voids within concrete mixes.

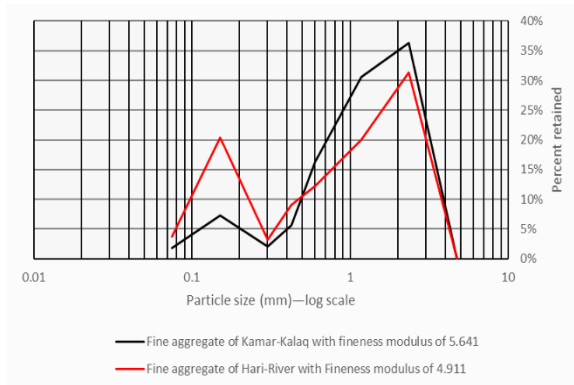


Figure 9. Comparison of percent retained on sieves for fine aggregate samples of Kamar-Kalaq and Hari-River

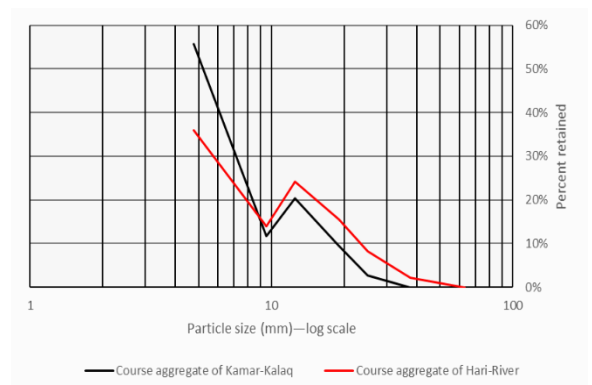


Figure 10. Comparison of percent retained on sieves for course aggregate samples of Kamar-Kalaq and Hari-River

Tables 1 and 2 present the results of compression tests conducted on both Hari-River and Kamar-Kalaq soils. The data illustrates that Hari-River exhibits higher strength levels in both the 7-day and 28-day tests. Specifically, the average of three 7-day tests for Hari-River is recorded at 17.3 MPa, whereas it is only 15.1 MPa for Kamar-Kalaq. Similarly, the average of 28-day tests for Hari-River stands at 27.8 MPa, compared to 23.4 MPa for Kamar-Kalaq. This superiority can be primarily attributed to Hari-River's superior grading in comparison to Kamar-Kalaq, as well as its lower clay particle content.

28-Day Test		7-Day Test	
Test Number	Result (MP)	Test Number	Result (MP)
1	28.3	1	18
2	27	2	16.1
3	28	3	17.7
Average	27.8	Average	17.3

Table 1. Displaying the results of compressive strength tests at 7 and 28-days for Hari-River

28-Day Test		7-Day Test	
Test Number	Result (MP)	Test Number	Result (MP)
1	23	1	14
2	24	2	16.3
3	23.1	3	15
Average	23.4	Average	15.1

Table 2. Displaying the results of compressive strength tests at 7 and 28-days for Kamar-Kalaq

Figures 11 and 12 depict the shape of aggregates for Hari-River on the right and Kamar-Kalaq on the left. In Hari-River, where aggregates are primarily exposed to water flow, they have undergone rolling, transitioning from angular to predominantly rounded shapes. Conversely, aggregates in Kamar-Kalaq largely maintain their angular form, which enhances interlocking during mixing. While this angular characteristic is advantageous for Kamar-Kalaq, a thorough analysis of its aggregates reveals the presence of voids within them, potentially leading to

increased water absorption. Despite the rounded shape of Hari-River's aggregates, it's noteworthy that they are solid with no voids present.



Figure 11. Shows comparison of aggregate shapes between Kamar-Kalaq (right) and Hari-River (left) after sieving



Figure 12. Shows comparison of aggregate shapes between Kamar-Kalaq (right) and Hari-River (left) after sieving

CONCLUSION

This study aimed to compare two commonly utilized riverbed aggregates in the Herat province. By meticulously examining key parameters such as clay content, gradation, aggregate shape, and compressive strength, the research sought to ascertain the optimal choice for concrete production. From the findings of this study, the following conclusions can be drawn.

1. The Kamar-Kalaq region exhibits a high percentage of clay particles, resulting in increased water absorption and consequently lower strength compared to Hari-River.
2. Kamar-Kalaq aggregates contain numerous small voids, which retain water. Coupled with the inadequate gradation of its fine aggregate, it becomes challenging for finer particles to fill these gaps, ultimately leading to reduced strength.
3. Hari-River demonstrates a significantly superior overall gradation compared to Kamar-Kalaq.
4. On average, Hari-River displays a 20% higher compression strength than Kamar-Kalaq.
5. Based on these findings, Hari-River is recommended over Kamar-Kalaq for construction purposes in the Herat Province.

Declaration

- **Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- **Competing interests**

The authors declare that they have no competing interests.

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